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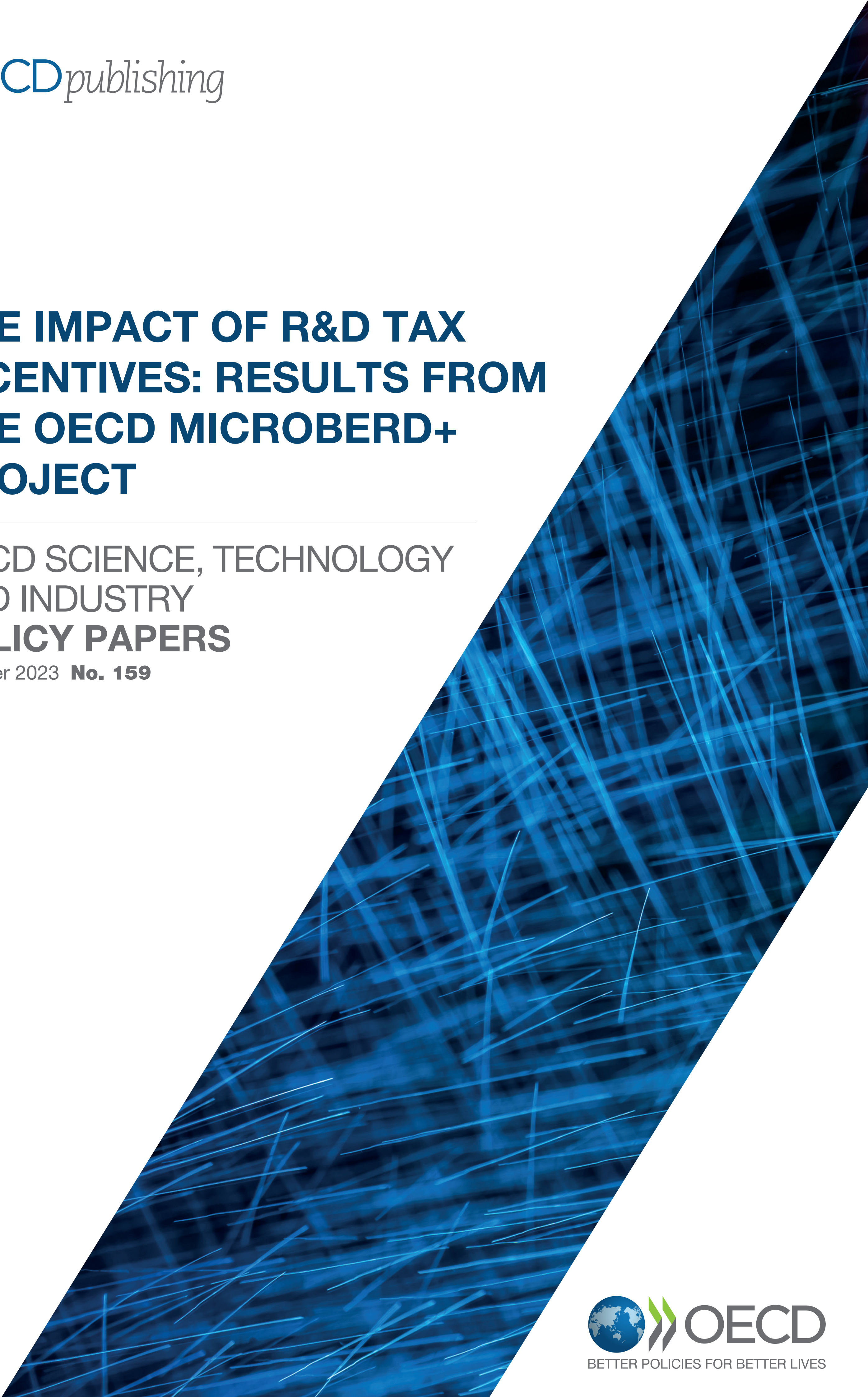

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The Impact of R&D Tax Incentives: Results from the OECD microBeRD+ Project

By Silvia Appelt, Matej Bajgar, Chiara Criscuolo and Fernando Galindo-Rueda
(OECD Directorate for Science, Technology and Innovation)

This document reports on the final output of the OECD microBeRD+ project. Drawing on the outcomes of previous work, this study presents new evidence on the impact of business R&D support policies – tax incentives and direct forms of support – on business R&D investment (R&D input additionality) and the innovation and economic performance of firms (R&D output additionality). The report also provides an exploratory analysis of R&D spillovers.

Keywords: Science and technology, Tax, Innovation

JEL codes: O38, H25, L25

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The microBeRD project adopts a distributed approach towards the analysis of business R&D microdata, characterised by a collaboration between the OECD Secretariat and designated official national experts with access to the confidential R&D, public support microdata and other relevant micro-data sources such as innovation survey, structural business survey (SBS) and patent microdata. This unique arrangement allows the implementation of a common and centrally developed code which provides the basis for the harmonised analysis of cross-country microdata while respecting access conditions to nationally held, confidential business microdata. Figures may differ or appear to differ from official R&D, business innovation and structural business statistics owing to different methodologies adopted for the purpose of micro-data analysis. The estimates presented should be taken as experimental and are not intended as substitutes for existing official statistics.

The OECD wishes to thank all the national experts from the microBeRD network which comprised 22 OECD countries in the second (2020-2023) phase of the microBeRD project: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, and the United Kingdom. This project and the results contained in this report would not have been possible without their knowledge, dedication, and patience.

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The submission of data by the national contributing organisations does not imply an endorsement of the methods or policy recommendations made in this report. The OECD is solely responsible for the drafting of the distributed code, analytical results and conclusions, which have been declassified by the OECD Committee on Industry, Innovation and Entrepreneurship (CIIE) and OECD Committee for Scientific and Technological Policy (CSTP).

List of contributors to the microBeRD expert network –2020-2023

Australia	Sasan Bakhtiari, Australian Department of Industry, Innovation and Science
	Andrew Watterson, Australian Department of Industry, Innovation and Science
	Mink Nguyen, Australian Department of Industry, Innovation and Science
	Francesco Tornatore, Australian Bureau of Statistics
	David Kennedy, Australian Bureau of Statistics
Austria	Andreas Schiefer, Statistics Austria
	Karin Bauer, Statistics Austria
Belgium	Karl Boosten, Belgian Science Policy
	Michel Dumont, Federal Planning Bureau Belgium
Canada	Ryan Kelly, Innovation, Science and Economic Development Canada
	Haig Mc Carrell, Statistics Canada
	Lucy Chung, Statistics Canada
	Charlene Lonmo, Statistics Canada
	Gregory Maloney, Statistics Canada
Chile	Maria Jose Bravo Pizarro, Ministry of Economy, Development and Tourism Chile
	Heinz Rodrigo Doebbel Aponte, Ministry of Economy, Development and Tourism Chile
	Antonio Martner, Ministry of Economy, Development and Tourism Chile
Czech Republic	Martin Mana, Czech Statistical Office
	Martin Srholec, CERGE-EI and Czech Statistical Office
France	Margot Perben, French Ministry of Higher Education, Research and Innovation
	Théophile Desolle, French Ministry of Higher Education, Research and Innovation
Germany	Thu-Van Nguyen, Stifterverband Germany
Hungary	Tibor Keresztély, Hungarian Ministry for National Economy
	Katalin Horváth, Hungarian Ministry for National Economy
	Péter Tóth, Hungarian Ministry for National Economy
	Ilona Cserháti, Hungarian Ministry for National Economy
Ireland	Donough Lawlor, Revenue Commissioners
	Jean Acheson, Revenue Commissioners
	Keith Walsh, Revenue Commissioners
Israel	Riki Kaduri, Central Bureau of Statistics of Israel
	Ayelet Benbassat, Central Bureau of Statistics of Israel
Italy	Antonella Caiumi, Italian National Institute of Statistics
	Valeria Mastrostefano, Italian National Institute of Statistics
Japan	Tomohiro Ijichi, Japanese National Institute of Science and Technology Policy
	Yuya Ikeda, Japanese National Institute of Science and Technology Policy
Netherlands	Stan Frenken, Statistics Netherlands
	Linda Bruls, Statistics Netherlands
	Piet Donselaar, Ministry of Economic Affairs and Climate Policy
New Zealand	Simon Wakeman, New Zealand Ministry of Business, Innovation and Employment
	Hemi Williscroft, New Zealand Ministry of Business, Innovation and Employment
	Jesse Robertson, New Zealand Ministry of Business, Innovation and Employment
Norway	Marina Rybalka, Statistics Norway
	Erik Fjaerli, Statistics Norway
Portugal	Filomena Oliveira, Portuguese Directorate General of Education and Science Statistics
	Ana Martins, Portuguese Directorate General of Education and Science Statistics
Slovak Republic	Peter Tóth, University of Economics in Bratislava
	Boris Frankovič, Statistical Office of the Slovak Republic
	Ján Pestún, Statistical Office of the Slovak Republic
Spain	Joseba Sanmartín Sola, Spanish Foundation for Science and Technology
Sweden	Petter Ehn Wingårdh, Statistics Sweden
	Nils Adriansson, Statistics Sweden
Switzerland	Sandra Plaza, Federal Statistical Bureau Switzerland
United Kingdom	Kyle Jones, Russell Black and Lilly Taylor, UK Office for National Statistics

Executive summary

There is wide consensus on the key role of research and development (R&D) as a driver of innovation economic performance and social wellbeing. To address failures in the market for research and development, governments worldwide strive to boost R&D investment among firms using financial support instruments. Governments increasingly use the tax system as an inducement mechanism. In 2020, R&D tax incentives accounted for around 55% of total government support for business R&D in the OECD area, up from 30% in 2000. This expansion raises important policy questions about the effectiveness of different policy tools in promoting R&D, innovation and economic performance, the heterogeneity of these effects across different types of firms and interaction of different policies.

The OECD microBeRD project studies the incidence and impact of public support for business R&D using a "distributed" approach in the analysis of confidential microdata, assessing policy impacts within and across countries. The micro-data based analysis consist of two components – a cross-country analysis based on micro-aggregated data and within-country firm-level analyses applying a harmonised methodology. This "hybrid" methodology combines the benefits of macro level analysis, through richer cross-country comparisons of policy levers and the generalisability of results, with those of micro level studies, capturing the heterogeneity of effects across different types of firms.

This report presents the latest results from microBeRD+, the second phase of the OECD microBeRD project (2020-2023), which compared with the first phase, provides a more in-depth analysis of R&D input additionality and extends the analysis to the estimation of R&D output additionality and spillovers, leveraging extended and updated microdata for the 2000-19 period. The study of R&D input additionality covers the largest number of countries (21 for the cross-country study and new firm-level analysis for 5). Many elements of this analysis can be performed based on business R&D survey data alone. In contrast, the study of output additionality and spillovers, requiring the linking to data on innovation and economic outputs, covers a reduced set of countries, namely 10 for the cross-country study and for the firm-level analysis of R&D output additionality and spillovers, 14 and 5 countries respectively.

The **preliminary findings from microBeRD+** address the following policy questions relating to R&D input and output additionality:

R&D input additionality

- **How effective are R&D tax incentives in raising business R&D investment?** The cross-country analysis, which takes into account the fact that not all R&D performing firms receive tax relief, yields a gross incrementality ratio (IR) of around 1.4 (one extra unit of R&D tax support translates into 1.4 extra units of R&D). The effect of tax incentives on experimental development is found to be more than three times as large as the effect on basic and applied research.
- **How does the effect of R&D tax incentives vary across different types of firms?** The effect of tax incentives is larger for small (IR: 1.6) and medium-sized (IR: 1.4) than for large firms (IR: 0.4). In the case of both research and experimental development, the higher responsiveness of smaller

firms to tax support is found to be driven by their lower level of initial R&D performance rather than firm size as such. The comparative advantage of tax incentives in boosting experimental development vs research applies to all size classes but is more pronounced for large compared to medium-sized and small companies.

- **How do tax and direct support for R&D interact?** The analysis shows a similar degree of input additionality for direct funding (IR: 1.4) compared to tax support (IR: 1.4) and hints at the complementarity of direct and indirect support measures. It should be noted that most countries prevent direct funded R&D amounts to be claimed for tax purposes.
- **Does the design of R&D tax incentives influence input additionality?** A new policy design analysis suggests that firms' responsiveness to tax support is nearly twice as large when refund provisions are available in the case of loss, and three times as large when tax incentives are redeemable against payroll taxes and thus disconnected from the profit situation of firms. Refundability however is certain to represent a higher cost for governments.
- **How effective are tax and direct support in raising business R&D in individual countries?** The new firm-level estimates of the effect of tax and direct support on business R&D, available for Canada, Italy, New Zealand, the Netherlands, the Slovak Republic and the United Kingdom, are broadly consistent with the input additionality effects found in the cross-country study.

Exploratory analysis of R&D output additionality and spillovers

- **How large are the economic returns to business R&D and spillovers from R&D?** Exploratory analysis using matched OECD microBeRD and MultiProd data at country-industry-size level indicate a positive and statistically significant effect of business R&D on economic performance. Evidence of relatively large returns from R&D conducted upstream to a given industry are indicative of potential R&D spillovers.
- **How effective are tax incentives and direct funding in raising business innovation?** The firm-level analysis of impacts on business innovation, which need not just result from R&D activity, provides so far no concrete evidence of impact. However, there is some evidence of a positive effect of R&D tax incentives and direct funding on patenting activity.
- **What is the impact of R&D tax incentives and direct funding in raising firms' economic performance? How large are the private and social returns to R&D?** Preliminary firm-level analysis for 14 countries provide some evidence for a positive effect of tax and direct support on economic outcomes such as sales, employment and labour productivity in most of the countries concerned. The pilot firm-level analysis of economic returns to R&D, available for a subset of 5 countries, suggests that the social returns to R&D are on average twice as large as the private returns due to significant knowledge spillovers.

microBeRD+ has contributed to developing impact analysis capabilities within and across countries, by extending the approach to newly participating countries, overcoming data access and use challenges through dialogue, and promoting record-linking between R&D input and output data. This unique multi-country infrastructure represents a valuable resource for future policy analysis and learning.

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1 Introduction

Investment in research and development (R&D) is a key factor driving innovation and economic growth. Businesses play a major role as R&D performers in most market economies, around 70% of the total R&D in OECD economies is performed within private or public enterprises. However, this is only to some extent possible due to a combination of policies and interventions. Most often, financial support is provided to firms with the intention of correcting or alleviating difficulties to appropriate the returns to their investment in new knowledge and shortcomings in the market for the financing of risky projects, especially for small start-up firms without collateral. The presence of positive externalities from R&D and the financial constraints make firms invest in R&D less than would be socially optimal. Several studies have found social economic returns to R&D (returns to the entire economy) to be substantially larger than private returns (returns to the investing firm).[1]

Governments combine various financial instruments to counteract these market failures and induce companies to increase or re-orient their R&D spending. One major class of instruments focus on supporting the inputs of the R&D activity. This might be for example in the form of payments for R&D services rendered to government entities, who act as customers, or unconditional payments such as grants, where the condition for support is the conduct of R&D projects over which the firm has complete control. These direct forms of funding can also be complemented by support mechanisms that, while still linked to the R&D activity of firms, are potentially contingent on other elements. For example, in the case of tax relief measures for R&D expenditures. the financial support received can depend on the firm's tax liability.[2] Over the last decade, expenditure-based R&D tax incentives, have emerged as the primary R&D support tool in many OECD countries (Appelt et al., 2016). In 2022, 33 of the 38 OECD countries offer R&D tax incentives, up from 19 OECD countries in 2000 (OECD, 2023a).

The OECD launched the microBeRD project in 2016 to shed light on the distribution and structure of business R&D (BERD) and the heterogeneity in the use and impact of tax and direct support measures for BERD across different types of firms and countries. microBeRD is a joint project of the OECD Committee on Industry, Innovation and Entrepreneurship (CIIE) and the Committee for Scientific and Technological Policy (CSTP), implemented through the OECD Working Party of National Experts on Science and Technology Indicators (NESTI) with support from the EU Horizon 2020 programme. The project is designed as a co-ordinated statistical analysis of the impact of business R&D support policies, applying a

[1] Bloom, Van Reenen and Williams (2019) for a review of studies estimating spillovers from business R&D. For recent work on the role of unintended spillovers vis-à-vis markets for technology, see Arqué-Castells and Spulber (2022), and for evidence on the magnitude of spillovers from basic vs applied research, see Akcigit et al. (2021).

[2] Becker (2015) and Bloom, Van Reenen and Williams (2019) take a broad look at the various policies for boosting business innovation. For an excellent survey of the literature on tax policy for innovation, including income-based R&D tax incentives ("patent boxes"), see Hall (2019), and for a recent study on the effect of corporate and personal taxes on innovation in the United States over the twentieth century, see Akcigit et al. (2022).

“distributed” approach to the empirical analysis of business R&D, tax relief and other relevant micro-data sources based on a close collaboration with national experts with access to confidential micro-data.

In the first phase (2016-2019), the microBeRD project (OECD2020a, OECD2020b) explored the effectiveness of R&D tax incentives and direct funding in raising business R&D investment, exploiting the variation in government support within and across countries. In the second phase of this project, microBeRD+ (2020-2023) aimed to extend and deepen the existing descriptive and impact-oriented analysis undertaken in the first phase of the project. In addition to a more in-depth, descriptive analysis of business R&D performance and funding (OECD, 2022), microBeRD+ sought out to:

- extend and deepen the existing micro-data based analysis of the effect of business R&D support policies on business R&D investment (R&D input additionality) and shed light on the role of policy design.
- explore the impact of R&D tax incentives and direct funding on innovation (e.g. introducing new products and services, filing patents) and economic outcomes (e.g. employment, productivity growth), i.e. R&D output additionality, as well as the extent of knowledge spillovers from R&D induced by public support.

This report presents the preliminary results from the extended R&D input additionality and pilot analysis of R&D output additionality and spillovers undertaken as part of microBeRD+. Input additionality is a necessary (yet not sufficient) condition for output additionality (Appelt et al., 2016), i.e. improved innovation and economic performance. The private and social economic returns to R&D may in turn differ due to spillovers. The micro-databased analysis comprises two elements: (1) a cross-country impact analysis based on pooled micro-aggregated data for 21 OECD countries; and (2) within-country firm-level regression analyses. While the cross-country analysis explores the link between business R&D support policies and the different outcomes of policy interest at the level of groups of firms in the same country, industry and size class (or, in selected analyses, at the level of groups of firms in the same country and industry), the within-country firm-level analyses explore these effects at the level of individual firms. This “hybrid” approach combines some of the advantages of cross-country studies (e.g. generalisability, rich cross-country variation in the R&D support policy mix and R&D tax incentive design), for example those based on country or industry-level data, with the strengths of country-specific studies undertaken at the level of the firm (e.g. the ability to explore the heterogeneity of effects across different types of firms and impact mechanisms). Furthermore, these microdata-based outputs which, designed and checked to be non-disclosive, do not present a confidentiality problem.

The remainder of the report is structured as follows. Section 2 lays out the microBeRD+ approach to microdata analysis, describing the data sources drawn upon and methodological approach for assessing the R&D input and output additionality of business R&D support policies, including magnitude of private and social returns to R&D. Section 3 presents the results from the extended R&D input additionality analysis, including new evidence on the role of R&D tax incentive design features. Section 4 follows with complementary and preliminary evidence from the pilot analysis of R&D output additionality and spillovers. Section 5 concludes by summarising the main findings of the report.

2 Data and methodological approach

Grounded on collaboration with national experts with access to the confidential R&D, public support and other relevant microdata sources within participating countries, the broader microBeRD methodology has been extensively described in OECD (2020a), outlining the key principles and procedures of the distributed analysis of R&D microdata, key data sources used, as well as the approach towards harmonising data and estimating the impacts of government support for R&D. This section focuses on describing the novel elements introduced in microBeRD+.

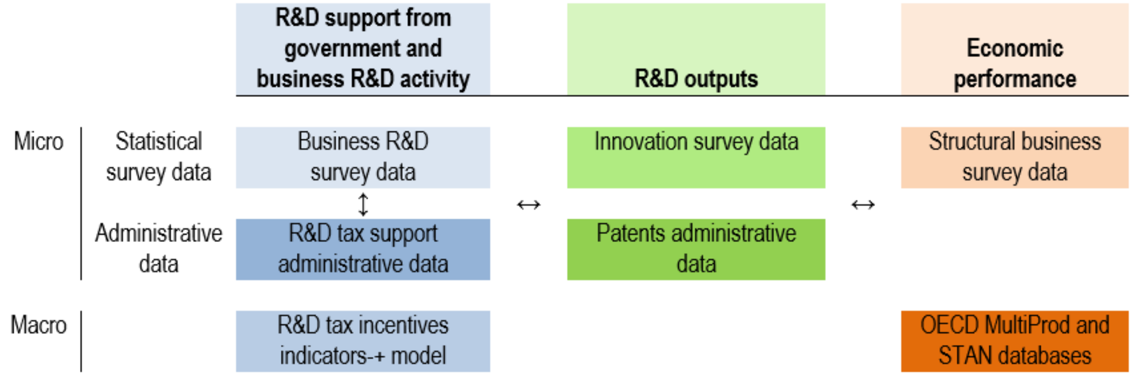
2.1. Data inputs for the distributed analysis

The microBeRD project draws on two core microdata sources (OECD, 2020a) - business R&D survey data and, in some cases, when available, administrative microdata on tax relief for R&D. The approach adopted in the microBeRD project is to estimate the implications of R&D tax relief provisions through the calculation of the B-Index measure[3] at the level of each firm (OECD, 2020a), leveraging information available in business R&D microdata. Since R&D surveys do not always contain information on tax support, the linking of survey and administrative data allows to identify which R&D performing companies effectively claim R&D tax incentives. Data on R&D support from government and business R&D activity provide the basis for the analysis of R&D input additionality. The processing of R&D input microdata follows a common approach to ensure data harmonisation and support a robust analysis across countries (OECD, 2020a).

As depicted in Figure 1, an extended set of sources underpin the distributed analysis in the second phase of the microBeRD project. In addition to the two core microdata sources, microBeRD+ leverages innovation survey, structural business survey (SBS) and patent microdata, where available, to assess the impact of public support for business R&D on innovation and economic outcomes.

[3] Aggregate OECD indicators on tax subsidy rates for R&D, calculated as 1 minus the B-Index, provide an indication of the potential R&D tax subsidy that companies under different scenarios may claim given their individual characteristics. For additional details on the OECD B-Index methodology, see (OECD, 2023b).

Figure 1. Micro and macro- data sources used in microBeRD+



Source: OECD own elaboration.

Table 1 provides an overview of microdata availability and scope of microdata extensions. Among the 22 countries for which the input additionality analysis is possible, the linking of innovation survey data is reported as potentially feasible in 14 countries (i.e. around two thirds of countries). This number drops to 11 countries for SBS and to 8 countries in the case of patent microdata.

Table 1. Microdata availability

	microBeRD+ core microdata availability		
	R&D survey only	**R&D survey + Tax relief data**	**Tax relief data only**
	7 countries: AUT, CHE, DEU, ESP, GBR, ISR, JPN	14 countries: AUS, BEL, CAN, CHL, CZE, FRA, HUN, ITA, NLD, NOR, NZL, PRT, SVK, SWE	1 country: IRL
	microBeRD+ microdata extensions		
Status	**Innovation survey**	**Patents**	**Structural business survey (SBS)**
Linked	10 countries: CAN, CZE, FRA, GBR, ITA, JPN, NLD, PRT, SWE, NOR	7 countries: AUS, CAN, CZE, FRA, JPN, NLD, NOR	10 countries: AUS, CAN, CZE, FRA, GBR, ITA, NLD, NZL, NOR, SWE
Linkable	4 countries: AUS, BEL, NZL, SVK	1 country: ITA	1 country: SVK
Variables	Employment, turnover, indicators of product (types, turnover, new to market) and process innovation (types), innovation expenditure (R&D, other), patent filing, survey weights	Patent application family stocks are constructed using the perpetual inventory method with a homogeneous 15% annual discount rate. Annual count of all/international/domestic patents; Stock of all/international/domestic patents	Employment (FTE, headcount); Birth year/age; Total labour cost; Gross output (sales can be used if gross output is unavailable); Value added; Investment; Capital stock
	Core microdata infrastructure		
	AUT, CHE, DEU, ESP, HUN, IRL		

Note: The panel on data extension does not include information for Chile and Israel. In the case of France, the business R&D survey also contains information on patent filings.
Patent application families, using the application year of the first application within each family. Patent families are considered "international" if at least one filing within a given family is with one of the four big patent offices (USPTO, EPO, JPO, WIPO).
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Among those countries that have already undertaken the data linking, a majority have participated in microBeRD+, contributing to the cross-country analysis based on micro-aggregated data and/or the within-country analysis based on firm-level data. Table A.1 provides an overview of the status of country participation in the two components of the microdata-based analysis undertaken as part of microBeRD+, distinguishing between the extended R&D input analysis and pilot analysis of R&D output additionality and spillovers and the different types of microdata sources employed in each analysis.

2.2. Cross-country analysis based on micro-aggregated data

As described in OECD (2020a), the micro-aggregated indicators generated in the first phase of the microBeRD project capture rich information on R&D performance, funding and employment, the theoretical implied marginal R&D tax subsidy rates (based on the B-Index) and actual amounts of R&D tax relief received by firms, where relevant tax relief microdata are available. Micro-aggregated statistics mainly consist of statistical moments – counts, means and percentiles (10th, 25th, 50th, 75th and 90th) – of the underlying variables. These can apply to the primary variables collected in surveys, or derived ratios thereof, such as firm-level R&D intensity (R&D as percentage of sales). Micro-aggregated indicators also include measures of dispersion (standard deviation) and concentration metrics. The statistics are calculated for all firms and various subgroups of firms defined, for example, by STAN A38 industry classification, size class (small, medium-sized, large), age (young, old), ownership (part of group, foreign-owned) or various interactions of these characteristics.

In microBeRD+, the statistics collected during the first phase were recalculated, incorporating some new decompositions, minor corrections and, where applicable, an extended sample period. In addition, some new micro-aggregated indicators were compiled based on the new microdata sources in the analysis, capturing information on business innovation, patenting and economic performance.

R&D input additionality

Baseline analysis

The estimation is based on an econometric model that links firms' decisions to invest in R&D to the user cost of R&D. The latter consists of two elements: an economic component (sum of economic depreciation and real interest rate) and a tax component – the B-Index – that captures features of the general tax system, including the implications of R&D tax incentives (OECD, 2021). Tax incentives, where available, reduce the B-Index. Using micro-aggregated data on business R&D expenditure and the B-Index at **country-industry-firm size-year level**, the cross-country regression analysis in the log-log specification estimates the R&D price elasticity of business R&D, i.e. the percentage change in R&D investment resulting from a 1% reduction in the user cost of R&D:

$$\boldsymbol{logY_{cist}} = \sum_{g\in G} \boldsymbol{\beta_g^{TAX}}\ \boldsymbol{logBIndex_{cist}} + \boldsymbol{\beta^{VA} logVA_{cit}} + \boldsymbol{\gamma_{cis}} + \boldsymbol{\gamma_{ist}} + \boldsymbol{\varepsilon_{cist}} \qquad \text{Equation 1}$$

The main outcome variable of interest (Y_{cist}) is total intramural R&D expenditure by firms in country *c*, industry *i*, size class *s* and year t. In addition, the analysis adopts a range of other outcome variables to test if the effects differ across different types of R&D costs. $Bindex_{cist}$ is the R&D tax incentive policy variable in the micro-aggregated analysis, representing the mean B-index (profit scenario) for each group of firms. This variable enters the analysis in log terms. The coefficient β_g^{TAX} identifies the user-cost elasticity, i.e. the proportional change in total intramural R&D of firms in a given group for a percentage change in the average B-index for that group of firms. The elasticities can be allowed to vary across different groups of firms (e.g. there can be a different β_g^{TAX} for small, medium and large firms). This allows for the estimation of heterogeneous effects of R&D tax incentives across different types of firms.

Industry-level value added (VA_{cit}), sourced from the OECD STAN database (http://oe.cd/stan), enters the regression as control variable to account for industry output. All regressions control for a rich set of fixed effects. The term γ_{cis} captures idiosyncratic characteristics of firms in a particular country, industry and size class (country-industry-size fixed effects) that do not change over time. This implies that the regression analysis exploits only the variation within country-industry-firm size units over time. Moreover, the regression analysis controls for industry-size class-year fixed effects (γ_{ist}); by doing so, it controls, for example, for the differential effects of the global economic slowdown on the R&D performance of firms of particular size in a particular industry. Finally, ε_{cist} is a time-varying residual – a summary term for effects not captured by any of the other variables.

A potential issue with defining observations by firm size classes is that as firms grow or become smaller, they can move from one size class to another size classes. In particular, if R&D tax incentives help firms grow, some firms, and their R&D, will move to larger size classes. This will lead to underestimating the effects of R&D tax incentive on smaller firms and overestimating them for larger firms. However, while plausible in theory, the issue is unlikely to be quantitatively important or change conclusions of the study. Firstly, the size classes used in the analysis are quite broad, so there will not be many firms changing size classes in any given year. Secondly, the results shown below indicate much *stronger* effects for smaller firms, which is exactly the opposite of the possible bias due to firms changing data cells. This means that the heterogeneity of effects found in the analysis would be, if anything, even more pronounced if this issue could be corrected.

The B-Index is typically introduced as exogenous policy variable in cross-country studies based on country or industry level data (Guellec and Van Pottelsberghe De La Potterie, 2003; Thomson, 2017). At the micro level, however, the B-Index depends on the level of business R&D expenditure of each firm (e.g. the rate of R&D tax credit is reduced once a certain R&D expenditure threshold is reached). This could render the B-Index endogenous. To address the potential endogeneity of the micro-aggregated B-Index indicator and avoid estimation bias, a synthetic version of the B-Index ($BIndex_t^{syn}$) indicator (Agrawal et al., 2020; Rao, 2016) is adopted in the main specifications of the cross-country analysis. The firm-level synthetic measure of the B-Index (in period t) is obtained by applying the R&D tax incentive design in year t to the R&D performance of firms in year t-2. This ensures that the current user cost of R&D does not depend on the level and structure of contemporary R&D spending.

$$\boldsymbol{BIndex_t^{syn2} := BIndex_t(RD_{t-2})} \qquad \text{Equation 2}$$

$BIndex_{cist}$ or $BIndex_{cist}^{syn2}$ do not reflect whether firms actually use R&D tax incentives. For this reason, the estimated R&D price elasticities can be seen as “intention-to-treat” estimates which are likely to underestimate the effect of R&D tax incentives for firms that actually used them. To explore this, an adjusted version of the B-Index indicator that takes into account the actual uptake of R&D tax support by firms is calculated for the subset of countries where R&D tax relief microdata are available. For firms that receive R&D tax support, the tax support-based version of the B-Index is identical to the standard B-Index indicator ($BIndex_t$). In the case of firms that do not receive such support, R&D tax incentive design features are disregarded in the computation of the B-Index and only baseline tax deductions – expensing of current expenditure and standard depreciation provisions for capital expenditures – are accounted for ($BIndex_t^{Baseline}$).

$$\boldsymbol{BIndex_t^{Tax} \coloneqq BIndex_t \ if \ tax \ support} \qquad \text{Equation 3}$$

$$\boldsymbol{BIndex_t^{Tax}} := \boldsymbol{BIndex_t^{Baseline}} \; \boldsymbol{if\ no\ tax\ support}$$

Tax incentive use is likely to be endogenous to firms' R&D performance, so estimating the effect of $BIndex_t^{Tax}$ would likely result in biased estimates. For this reason, an instrumental variables estimation (IV) is employed, where $BIndex_t^{Tax}$ is instrumented with the synthetic B-Index measure ($BIndex_{cist}^{syn2}$). To further explore the heterogeneity of the estimated effects, the B-Index variable ($BIndex_{cist}^{syn2}$) is interacted with various firm characteristics such as firm size, industry sector and initial R&D intensity. Table A.3 reports the full list of interaction variables.

The extended input additionality analysis performs two additional checks of the robustness of the methodology used to potential issues arising from the fact that the BIndex is calculated at the firm level and only then aggregated up to the country-industry-size class level.

The first robustness check is motivated by the observation that the B-Index is typically introduced as exogenous policy variable in cross-country studies based on country or industry level data (Guellec and Van Pottelsberghe De La Potterie, 2003; Thomson, 2017), but when calculated at the firm level, the B-Index depends on the level of business R&D expenditure of each firm (e.g. the tax incentive rate is reduced once a certain R&D expenditure threshold is reached). This could render the main explanatory variable endogenous. The implementation of an instrumental variable (IV) estimation, where the average (log) B-Index is instrumented with the synthetic B-Index measure that captures only policy changes, keeping the set of firms and their R&D expenditure fixed[4], aims to address this issue. The instrument is constructed in three steps. In the first step, the synthetic one-year and two-year log changes in the B-Index are calculated for each firm-year observation as follows:

$$d1logBIndex_{ft}{}^{syn1} := logBIndex_{ft}(RD_{t-1}) - logBIndex_{f(t-1)}(RD_{t-1})$$ Equation 4

$$d2logBIndex_{ft}{}^{syn2} := logBIndex_{ft}(RD_{t-2}) - logBIndex_{f(t-2)}(RD_{t-2}),$$ Equation 5

where $logBIndex_{f,t1}(RD_{t2})$ is obtained for firm *f* by applying the R&D tax incentive design in year *t1* to the R&D performance of firms in year *t2*. This approach ensures that R&D expenditure is kept fixed at the level in *t*-1 or *t-2* and only the R&D tax incentive design varies over time. In the second step, averages of $d1logBIndex_{ft}{}^{syn1}$ and $d2logBIndex_{ft}{}^{syn2}$ across firms in each country, industry, size class and year are taken to obtain $\overline{d1logBIndex}_{cist}^{syn1}$ and $\overline{d2logBIndex}_{cist}^{syn2}$ respectively. Finally, the instrument is calculated as a sum of the initial average log B-Index and stacked synthetic changes (i.e. cumulative synthetic changes). For countries where annual data are available, it is computed as:

$$\overline{logBIndex}_{cist}^{syn} = \overline{logBIndex}_{cis1} + \sum_{m=2}^{t} \overline{d1logBIndex}_{cism}^{syn1},$$ Equation 6

[4] A similar strategy has been exploited by a firm-level analysis of the US R&D tax credit by Rao (2016).

where $\overline{logBIndex}_{cis1}$ is the value of the average log B-Index in the first year of the sample.[5] For some countries, bi-annual data are available and 2-year synthetic changes are used in this case.[6]

The second robustness check examines the consequences of using an *unweighted* average BIndex within a country-industry-size class cell when the cell-level R&D performance is disproportionally driven by large R&D performers. A weighted average BIndex measure, based on each firm's R&D expenditure, is calculated. Since weights also enter the outcome variable and this may case endogeneity, the average R&D expenditure of each firm over time is used as weight.

Policy mix analysis

The extended input additionality analysis examines the role of direct forms of public R&D funding and their interaction with R&D tax incentives. Direct support is measured by the (logged) amount of direct funding received by firms in a given country, industry and size class ($\log DF_{cist-2}$). This additional policy variable enters the regressions as separate explanatory variables and interacted with the *B-Index* ($BIndex_{cist}^{syn}$).[7] The estimated equation is as follows:

$$\boldsymbol{logY_{cist}} = \boldsymbol{\beta^{TAX}\, logBIndex_{cist}} + \boldsymbol{\beta^{DF}\, \log DF_{cist-2}} + \boldsymbol{\beta^{TAXDF}\, logBIndex_{cist}} * \boldsymbol{\log DF_{cist-2}} + \boldsymbol{\beta^{VA} logVA_{cit}} + \boldsymbol{\gamma_{cis}} + \boldsymbol{\gamma_{it}} + \boldsymbol{\gamma_{st}} + \boldsymbol{\varepsilon_{cist}} \qquad \text{Equation 7}$$

By construction (government-financed BERD is one component of BERD), direct funding is directly linked to the contemporaneous level of intramural R&D. To avoid simultaneity bias, the direct funding variable is lagged by two years ($\log DF_{cist-2}$).[8] Moreover, own-funded intramural R&D is used as outcome variable, netting out the contribution of direct funding and other external sources of R&D funding.[9] This means that

[5] Note that the first component of the instrument (the initial average log B-Index) is time-invariant and, as such, does not affect the regression estimates, which control for country-industry-size class fixed effects (i.e. dropping the first component would leave the results unchanged). We include it to support intuitive interpretation of the instrument as a synthetic version of the endogenous explanatory variable and facilitate interpretation of descriptive statistics.

[6] A few countries have annual data for one part of the sample period and bi-annual for the other. In this case, we use a combination of annual and bi-annual synthetic changes to construct the instrument.

[7] In calculating the interaction term, direct support is normalised by the level of intramural R&D expenditure by firms in a given country-industry-size class group. This ensures that the interaction term captures the intensity of direct support and not just the number of firms in that country-industry-size class cell.

[8] R&D microdata for several countries are available only biannually, so two-year, rather than one-year, lags are employed throughout the report.

[9] Please note that despite the use of an outcome variable that does not include direct funding as a component, the direct funding variable could still be endogenous if country-size-industry groups that become more (less) active in the area of R&D also apply for and obtain more (fewer) R&D grants. For this reason, the results for direct support should be treated as exploratory and interpreted with caution.

the elasticity parameter estimated for direct funding represents a net elasticity, specifying the percentage change in BERD beyond the level of direct support provided. The R&D price elasticities estimated based on the B-Index reflect gross elasticities, by contrast, independent of whether the analysis adopts intramural R&D or own-funded intramural R&D as dependent variable.[10] They specify the percentage change in BERD gross of the R&D tax subsidy provided. While gross and net elasticities are not directly comparable, net incrementality ratios can be converted into gross incrementality ratios[11], facilitating a comparison of the input additionality of tax and direct support.

Table 2 presents the summary statistics for the outcome and explanatory variables employed in the micro-aggregated cross-country analysis of R&D input and output additionality. Thanks to the extensions of the underlying data, particularly adding more recent years, the estimation database counts 11715 country-industry-size class-year observations for which the baseline regressions in their simplest specification can be run, compared to about 9,700 in the initial R&D input additionality analysis (OECD, 2020a). However, not all variables are available for all these observations. More demanding specifications are necessarily based on smaller data samples.

Table 2. R&D input and output additionality analysis - summary statistics

	N	Mean	Median	SD	Min	Max
Input (2000-2017): country-industry-size						
Intramural R&D (000 USD)	11715	270767	29847	1150830	1	20672400
Labour (000 USD)	10929	6151675	48020	50423119	53	1027605888
Other current (000 USD)	10860	7391592	23012	68258958	0	1475605376
Capital (000 USD)	10698	1291277	5640	10255171	0	227499184
Research (000 USD)	9807	4411245	32737	36255416	0	782209600
Development (000 USD)	9774	11999908	34983	101437872	0	2099894400
Extramural R&D (000 USD)	8005	101437	5633	731555	0	36372192
Average intramural R&D (000 USD)	11715	4716	648	16479	0	719272
BIndex	11715	0.80	0.81	0.16	0.31	1.11
BindexSyn	8203	0.84	0.82	0.31	0.32	2.26
BindexTax	6110	0.85	0.88	0.13	0.39	1.11
BIndex (weighted	9869	0.812	0.836	0.165	-0.147	1.21
Value added (000 000 USD)	11325	0	0	0	0	1
Direct funding of BERD (000 USD)	10491	13150	1014	68484	0	1498448
Small	11715	35%	0%	48%	0%	100%
Medium	11715	34%	0%	47%	0%	100%
Large	11715	31%	0%	46%	0%	100%
Output (2000-2019) – country-industry						
Value added	5252	5765	1932	12470	12	170193
Employment (thousands)	5252	76	29	136	0	1417
Capital stock (millions USD)	5252	5897	1866	13079	13	141058

[10] Tax subsidies feature at least partially in firm's own financing of BERD (Appelt et al., 2019).

[11] For additional details on the derivation of incrementality ratios, see (OECD, 2020a).

Own-industry R&D capital stock (millions)	5252	1983	207	8534	2	108288
Upstream-industry R&D capital stock (millions)	5252	6094	2713	9837	62	64848

Note: The summary statistics presented in this table are based on micro-aggregated data. Observations are defined at the country-industry-size class level. See Table A.3 for variable definitions. Monetary variables are stated in 2005 US dollars using purchasing power parity exchange rates. For output additionality, the summary statistics presented in this table are based on linked OECD microBeRD and MultiProd data. Observations are defined at the country-industry level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

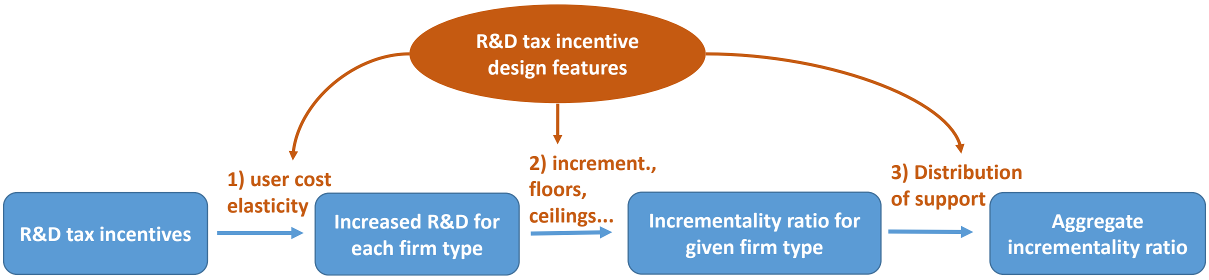
The median country-industry-size class group of firms incurs USD 30 million of intramural R&D expenditure, while the average is nearly 10 times larger. The average firm-level R&D performance within firm groups is about USD 650 000 at the median. Across firm groups, the average B-Index amounts to 0.80, implying that R&D tax incentives provide a sizeable marginal R&D subsidy rate of 20%. The average cluster receives about USD 13 million of direct funding, while the median receives around USD 1 million.

Policy design analysis

microBeRD+ explores whether, and how, the design of R&D tax incentives influences their effectiveness in encouraging business R&D investment. Focusing on R&D input additionality, and therefore implicitly assuming that the economic benefits of an additional unit of R&D are the same irrespective of which firm makes the investment. The effectiveness of R&D tax incentives in a given country can be measured by the aggregate country-level incrementality ratio, i.e. the ratio of the total extra R&D investment due to the tax incentives to the total costs to the public purse in the form of reduced tax revenues.

As Figure 2 shows, the design of R&D tax incentives may affect the aggregate (cross-country) incrementality ratio in several ways. Tax provisions could affect firms' responsiveness to available R&D tax incentives, reflected in the measured elasticity with respect to the BIndex. Furthermore, the design of R&D tax incentives could affect how much R&D tax support certain firms actually receive from governments. For a given elasticity level, this would show as a greater or smaller incrementality ratio for some group of firms. Policy design could also influence the overall distribution of R&D tax support across different types of firms (with heterogeneous elasticities) within countries and thus the overall aggregate incrementality ratio for a given country.

Figure 2. The link between design, firms' responsiveness and the effectiveness of R&D tax relief



Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

To give an example, R&D tax incentives may apply to all qualified R&D expenditures (volume-based) or only to the additional amount of R&D expenditure above a certain base amount (incremental). Incremental R&D tax incentives may (1) reduce the user cost elasticity because firms (of a given type) as firms are less motivated by such an incentive, but they may (2) reduce the costs of the incentive because only R&D

above a certain baseline is subsidised, and (3) lead to a greater share of the support going to small firms, which are comparatively more responsive to R&D tax incentives. microBeRD+ makes a first attempt to measure how the design of R&D tax incentives might affect their effectiveness in encouraging additional business R&D investment through these channels.

The R&D tax incentive design features accounted for in the analysis are summarised in Table 3. This includes the availability of a refund for loss-making companies, redeemability of tax incentives against payroll (e.g. withholding) taxes or social security contributions, presence of a limitation of the amount of qualifying R&D expenditure beyond which the tax subsidy rate is reduced (threshold) or becomes zero (ceiling), the availability of a preferential tax treatment of SMEs, in addition to other design features related to the type of tax instrument that is under consideration.

Table 3. R&D tax incentive design features accounted for in analysis

Design feature	Definition
Refund	R&D tax incentives are refundable (any excess claims on top of the tax liability can be paid in full or in part to the taxpayer) or redeemable against payroll and related taxes.[12]
Payroll	If the main tax relief measure in the country in terms of size is redeemable against payroll (e.g. withholding) taxes or social security contributions instead of corporate income taxes.
Limitation	A cap (upper ceiling) or threshold (pre-defined amount that implies a reduction in reduction in the size of the R&D tax credit or allowance rate or rate of refundability when qualifying R&D expenditure surpasses this level) applies to the value of R&D tax benefits and or value of qualifying R&D expenditures (intramural R&D and/or extramural R&D).
Preferential treatment of SMEs	R&D tax relief provisions entail enhanced tax credit/allowance rates or other more favourable terms (e.g. refundability) for SMEs.
Credit	A tax credit is an amount subtracted directly from the tax liability due from the beneficiary unit after the tax liability has been computed.
Allowance	Tax allowances or deductions subtract from the tax base before the tax liability is computed, reducing the taxable amount before assessing the tax.
Volume-based	Tax credit/allowance rates apply to the volume of qualifying R&D expenditures.
Incremental	Tax credit/allowance rates apply to R&D expenditures over and above of a pre-defined baseline amount
Hybrid	Tax incentive has both a volume-based and incremental component.

Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

To explore the role of R&D tax incentive design features, design dummy variables (defined at country size class level) are added to the cell-level regression analysis and interacted with (log) B-Index.

$$logY_{cist} = \sum_{g \in G} \beta_g^{TAX} \, logBIndex_{cist} * Design_{cst}^{RDTAX} + \beta^{VA} logVA_{cit} + \gamma_{cis} + \gamma_{it} + \gamma_{st} + \varepsilon_{cist} \quad \text{Equation 8}$$

[12] Tax offsets redeemable against payroll tax or social security contributions generally provide an alternative means to address the limited income tax liability problem. Such incentives, while limited to the payroll tax and social security liability of the corresponding tax period, unless alternative restrictions apply, are disconnected from the corporate tax liability of the firm and thus are in principle payable in both profit and loss-making scenarios.

As tax incentive design features are only observed for active R&D tax relief measures, the policy-mix analysis focuses on observations where R&D tax incentive schemes are in place.

Economic returns to R&D and spillovers

The number of countries in the microBeRD project that have so far linked their R&D microdata with information on innovation or economic performance is not sufficiently large to allow a cross-country estimation of R&D output additionality. For this reason, the micro-aggregated pilot analysis of output additionality relies for the moment on linked OECD microBeRD and MultiProd data at the level of countries, A38 industries and firm size classes. It focusses on the assessment of the private and social economic returns to business R&D investments which represents one key element in the evaluation of the economic impact of R&D tax incentives and direct government funding. The analysis follows the literature on estimating the private and social returns to R&D (see Hall *et al.*, 2010, for a review and discussion) and estimates a value-added production function given by

$$\mathrm{VA} = \mathrm{A}L^{\beta^L}K^{\beta^K}R^{\beta^{RD}}S^{\beta^S} \qquad \textbf{Equation 9}$$

where *A* is the industry total factor productivity, *L* is industry employment, *K* is industry fixed capital stock, *R* is industry's own stock of R&D capital, constructed from annual R&D investment using the perpetual inventory method and depreciation rate of 15%, and *S* is the spillover variable, constructed as the weighted average of the stocks of R&D capital in all other industries.

To estimate the economic impact of knowledge spillovers, econometric studies ordinarily adopt a measure of the stock of external knowledge which is constructed as a weighted sum of R&D capital stocks of "connected" sources external to the firm, industry or country. Weights are usually proportional to some proximity or flow intensity measure (e.g., derived based on patent classes, patent licensing or mobility of R&D personnel) between the recipient i and the assumed source j of the knowledge spillover and indicate the likelihood with which knowledge transmits from one party to another. The underlying assumption is that knowledge is more likely to diffuse, the larger the intensity of interaction or the proximity between the spillover recipient and provider.

As data limitations prevent the derivation of most of the proximity measures typically used in the literature, the measure of proximity between industries is based on an industry input-output matrix. In particular, for each industry *i*, the weights are given by the share of each industry *j* in inputs purchased by industry *i*. This approach captures spillovers from upstream firms to downstream firms, based on the idea that firms are likely to benefit and learn from knowledge created by companies from which they source inputs. Future analysis could also explore spillovers flowing in the opposite direction, from downstream buyers to upstream suppliers.

The shares are measured using country-specific input-output matrices from the OECD Inter-Country Input-Output database.[13] As available input-output matrices do not offer information by size class, the spillover variable does vary by country and industry but not by size class.

The production function is estimated using the following estimating equation:

$$logVA_{csit} = \beta^L logL_{csit} + \beta^K logK_{csit} + \beta^{RD} logR_{csit} + \beta^S logS_{cit} + \gamma_{cst} + \gamma_{ist} + \varepsilon_{csit} \qquad \textbf{Equation 10}$$

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[13] https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm

with observations defined in the same way as in the estimation of R&D input additionality, i.e. by countries, A38 industries, firm size classes and years.

β^{RD} is the elasticity of industry value added with respect to the stock of R&D capital, and the implied own-industry return to R&D investment can be calculated as this elasticity divided by the ratio of industry R&D stock to industry value added, $\rho = \frac{\beta^{RD}}{\frac{R}{VA}}$. The return to R&D in upstream industries can be defined in an analogous way.

The analysis implemented thus far looks at the returns to R&D irrespective of how the R&D is funded. To investigate the impact of public support for business R&D, additional analysis takes a reduced-form approach to specifically explore the economic effects of tax incentives and direct funding. It estimates the impact on value added and controls for employment and fixed capital, but rather than estimating elasticities with respect to R&D stocks, it estimates elasticities with respect to the B-Index and direct funding for business R&D:

$$logVA_{csit} = \beta^{L} logL_{csit} + \beta^{K} logK_{csit} + \beta^{Tax} logBIndex_{csit} + \beta^{Direct} logDirect_{csit} + \gamma_{cis} + \gamma_{ist} + \varepsilon_{csit} \quad \text{Equation 11}$$

Similar to the input-additionality analysis, the estimation controls for country-industry-size class fixed effects and for industry-size class-year fixed effects. The summary statistics for the outcome and explanatory variables employed in the R&D output additionality analysis are presented in Table 2.

2.3. Country-specific analysis based on firm level data

R&D input and R&D output additionality

Distributed regressions are implemented in a harmonised fashion on firm-level data in each participating country and make use of the within-country variation in the R&D and tax relief data across firms and over time. When studying input additionality, the primary outcome variable is the combined value of intramural and extramural R&D expenditure of each firm.[14] The impact on different types of R&D cost (current, capital, extramural), R&D employment and different types of R&D (research, experimental development) can also be investigated as part of the country specific firm-level analysis (OECD, 2020a).

The outcome variables (Table 4) used to analyse the innovation impacts of public support include a range of innovation survey indicators (e.g. introduction of new products/services, different types of process innovation) and the number of patents filed in a given year, leveraging patent data. The outcomes used to examine the impact of the public support on economic performance are employment, sales, value added, labour productivity (value added divided by employment) and average wage. All these variables can be found in SBS data, but the analysis additionally leverages information on employment and sales information from R&D surveys to investigate impacts on economic outcomes for countries where the

[14] Both intramural and extramural R&D expenditure can be affected by tax incentives, so it is desirable to analyse the impact of the tax incentives on both types of R&D expenditure. In the micro-aggregated estimation, adding up intramural and extramural expenditure might result in double-counting – intramural R&D of some firms can be funded by extramural R&D expenditure of other firms – so only intramural R&D was used as outcome in the baseline specification. In a firm-level analysis, however, the double-counting is not an issue, so both intramural and extramural R&D expenditure are included in the outcome variable.

microdata used in microBeRD do not include linked SBS data or where linked SBS records are available only for a strict subset of all observations.

The aim is to estimate the effect of tax incentives and direct support by assessing how the performance of firms in the presence of support differs from what would be observed in its absence. The key challenge is that firms' performance can be correlated with government R&D support for many reasons and not only because such support causes firms to increase their R&D expenditure and subsequently its innovation and economic outcomes. For example, when the value of R&D tax relief is calculated as a fixed percentage of each firm's R&D expenditure, firms performing more R&D will receive more tax relief even if tax subsidies have an effect on their R&D investments.[15] This creates a positive correlation between the level R&D performance and tax relief that reflects in part the fact that R&D expenditure increases the amount of R&D tax subsidies received rather than the other way round.

Table 4. Outcome variables used in the firm-level analysis of input and output additionality

Input additionality	
Intramural + extramural R&D	Log total intramural and extramural R&D expenditure
R&D employment	Log total R&D employment (full-time equivalents, headcounts if FTE not available)
Extramural	Log extramural R&D expenditure
Output additionality	
Innovation (innovation survey)	
Product innovation (goods)	During the last three years, did your enterprise introduce new or significantly improved goods?
Product innovation (services)	During the last three years, did your enterprise introduce new or significantly improved services?
Process innovation	During the last three years, did your enterprise introduce new or significantly improved manufacturing, logistics, delivery or distribution methods, or supporting activities for your processes?
Innovation (patent data)	
Log patents	Log (1+number of patent applications filed)
Economic	
R&D survey data	
Employment	Log total number of employees (headcounts)
Sales	Log sales
Structural business statistics	
Value added	Log value added
Labour productivity	Log labour productivity (value added / employment)
Average wage	Log average wage (costs of employees / employment)

Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Two distinct approaches are adopted in this paper to overcome this challenge and estimate the effect of R&D tax support on R&D, innovation and economic performance. The first approach compares firms that start using R&D tax incentives or receiving direct support to other similar firms that do not. The second approach exploits specific R&D tax incentive policy changes that increase the marginal tax subsidy rates for some firms while keeping them fixed for others.

[15] If R&D tax subsidy rates based on the B-Index were used as explanatory variable in the firm-level analysis, a similar problem would arise. For instance, in Australia and in Japan, SMEs are eligible for higher tax credit rates than large firms. As large firms on average perform more R&D than SMEs, this generates a negative correlation across firms between the tax subsidy rates they face and their R&D performance, even if R&D tax incentives actually increase R&D performance.

Difference-in-differences estimation based on business uptake of support

Although R&D tax incentives represent a market-based, non-discretionary policy tool that is, in principle, available to all R&D performing firms, not all eligible R&D performing firms use them. Some firms may not be aware of the availability of R&D tax relief provisions, others may be deterred by administration and compliance costs (reporting requirements, audits etc.), and yet others may rely on other forms of government support and not require additional funding. Among countries for which matched R&D survey and tax relief microdata are available, only about half of R&D performing firms (featuring in R&D surveys) receive R&D tax relief on average.

Compared to R&D tax incentives, direct support implies a higher degree of discretion on the part of government authorities which has implications for the impact estimation. R&D grants, for example, are subject to a multiple selection process. Eligibility may be more constrained and not all potentially eligible firms will decide to apply for an R&D grant; while only a fraction of applicants will actually receive a grant offer, which they may ultimately accept or reject. Across countries considered in the firm-level analysis based on receiving direct support, an average 19 % of R&D performers benefit from direct R&D funding.

This variation in business experience of R&D tax incentives and direct funding support can be used to compare the R&D performance of firms that receive support and those that do not.[16] The estimation approach exploits the idea that government support reduces the marginal cost of R&D only for those firms that receive this support, and consequently should stimulate only the R&D performance of support recipients. The fundamental estimation challenge is that it is not possible to observe the "counterfactual" – how much R&D the firms receiving R&D tax relief (or direct support) would have performed had they not received this support. Being unable to observe the counterfactual directly, the best alternative is to compare the firms that receive tax relief with that do not but *are otherwise as similar as possible*.

The approach to identify such firms– difference-in-differences with matching – combines two comparisons in an attempt to implement a valid counterfactual. A within firm-comparison of firms receiving support over time, i.e. prior to and after starting to receive support. This comparison is useful because it removes any time-invariant firm characteristics which could be correlated with receiving tax or direct support. The second comparison compares R&D support recipients ("treated firms") with otherwise similar firms that do not receive such support ("control group"). The treatment and control groups are constructed using a matching procedure. In the case of R&D tax incentives (direct funding), the treatment group consists of firms that are present in the data in at least one year during the 4-year period immediately before they start to receive R&D tax relief (direct support) and in at least one year during the 7-year period from the year in which they start to receive the support.[17] The time window over which the effects are estimated, thus, now includes 4 years before and 7 years after the year firms start receiving support. It has been extended relative to earlier microBeRD analyses (which used a window of 2 years before and 3 years after this point

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[16] For simplicity, the terms "direct support" and "R&D grants" are used interchangeably. It is, however, important to keep on mind that direct funding also includes government R&D contracts.

[17] Using T to denote the year of first receiving tax relief, firms are required to be observed in the data in years T-2, T-1, T, T+1 and T+2. This requirement is conditional on the R&D microdata being available for given years. For example, in a case where firms starting to use tax relief in year T and the microdata end in year T+2, the firms are kept in the treated set as long as they appear in the data in years T-2 to T+1. The same applies in the case of countries where the R&D microdata is collected only every other year.

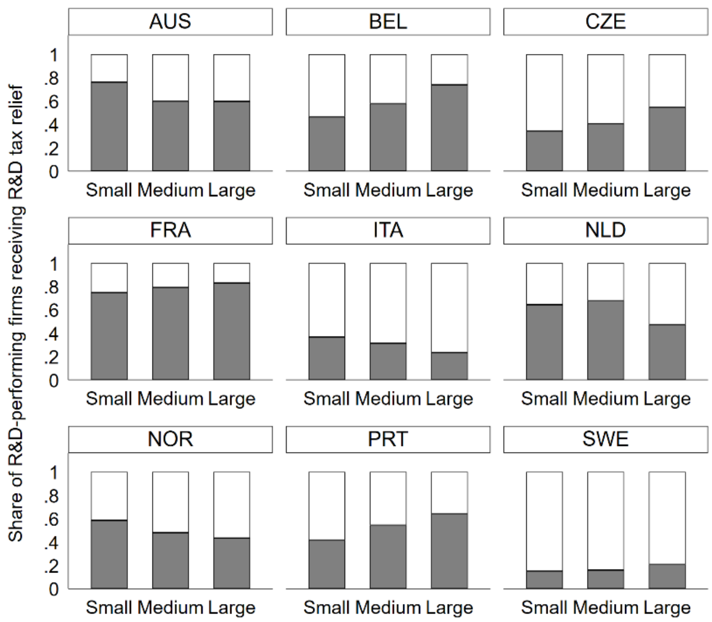
in time) to allow for a potential time lag between the increase in R&D investment and possible improvement in innovation and economic outcomes.

The analysis is thus conducted for firms with some level of R&D activity throughout the reference period. This is partly due to the fact that R&D surveys tend to track with certainty "known" R&D performers while they only sample, on a stratified random basis, the firms that may or may not conduct R&D. Instances where firms do not perform R&D continuously are excluded from the analysis, as the analysis examines changes in R&D performance. Therefore, the micro regressions identify the impact of tax support among continued R&D performers and abstract from changes at the extensive margin of R&D performance.

The treatment group consists of firms that switch from not receiving tax support to receiving it; while the counterfactual group is constrained to those who never receive support. This effectively excludes from the analysis companies that persistently receive public support throughout the analysis period. An alternative approach would entail comparing switching companies with companies that persistently receive support to identify whether the former "converge" with the latter. Such estimation choices may have different implications for different groups of firms.

Figure 3. Share of R&D-performing firms receiving R&D tax relief (2015 or latest)

By country and size class



Notes: This chart displays the share of R&D performing firms within a size class that use R&D tax relief. Figures refer to 2015, except for Australia, France, Norway where they refer to 2014. In the case of Belgium and Germany, figures correspond to 2013.
Source: OECD microBeRD, http://oe.cd/microberd, July 2023.

The use of R&D tax incentives may for instance vary across size classes, and if most firms in a certain size group use tax incentives it might be more suitable to compare them with firms in the same size class that permanently use R&D tax incentives rather than those few firms that do not rely on R&D tax relief. However, available micro-aggregated statistics (Figure 3) suggest that the differences in the use of R&D tax incentives (share of R&D performers that use tax support) across size classes are limited, and in the case of all countries where this estimation is undertaken, there is a sufficient number of R&D performing firms in all size classes that do not use tax relief and can serve as a control group.

Once the treatment and control groups are established[18], the impact of tax incentives (or direct support) is analysed by estimating the following relationship:[19]

$$\boldsymbol{logY_{it} = \beta_1 Recipient_{it} + \gamma_i + \gamma_t + \varepsilon_{it}},$$ **Equation 12**

Y_{it} is the outcome (e.g. total intramural and extramural R&D expenditure) for firm i in year t. The dummy variable $Recipient_{it}$ marks firms starting to receive R&D tax relief (or direct support). [20] It is equal to one for the treated firms after they start receiving government support. It equals zero for treated firms in previous years, while it is always zero for control ("never taker") firms. β_1 is the estimated effect of public support, which can be interpreted as the average treatment effect on the treated (ATT). The equation controls for time-invariant characteristics of each firm (firm fixed effects) and year fixed effects. ε_{it} is the

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[18] For each firm treated (starting to use R&D tax relief) in year T, a control group is constructed consisting of firms that appear in the data in the same years – never receiving tax relief – and belong to the same size class (small, medium, large), macro industry (manufacturing, other), initial R&D performance quintile and R&D grant receipt status. For direct support, the treatment and control groups are constructed in an analogous way with the exception that firm's R&D tax support receipt status is not included as a matching variable due to the restricted availability of such data across participating countries. This approach, called "coarsened exact matching" (CEM), links firms that show an exact match in terms of all matching variables (e.g. employment size), conditional on these variables being "coarsened" (transformed) to several discreet values (e.g. size classes). Unlike some other matching estimators, CEM is guaranteed to reduce the imbalance between treatment and control groups in terms of the variables used for matching, it automatically restricts data to a common support between the two groups, and it has a number of other desirable statistical properties (see Blackwell et al., 2009 and Iacus et al. 2011 and 2012). At the same time, it is intuitive and easy to implement in the context of a distributed regression analysis.

[19] The estimation is performed in Stata by first using the *cem* command to produce matching weights and then estimating weighted regressions with the *xtreg* command.

[20] Information about whether a firm receives direct support is available from the R&D survey. In the case of R&D tax incentives, identifying recipients crucially relies on a match of R&D survey and tax relief data. This means that the estimation for tax incentives is only feasible for countries where this match has been performed. For a few countries, firm-level estimates could not be produced due to data limitations (the R&D microdata available for analysis for Spain consisted of repeated cross-sections rather than a panel, and the microdata for Switzerland include only 4 waves spread over a 10-year period owing to the frequency with which business R&D surveys are undertaken in the country). Moreover, firm-level results are only reported when the analysis is based on a sufficiently large number of observations, specifically when both the number of treated firms and the number of control firms are at least 50.

residual.[21] Unlike earlier microBeRD analysis, the baseline equation now does not control for firm size (measured by sales when available and employment otherwise), because this is an outcome of interest. However, the matching accounts for firm size and robustness checks are performed to examine if controlling for firm size would affect the estimated input additionality and innovation effects.

At this stage, results based on R&D tax support uptake are reported for 11 countries: Australia, Belgium, Canada, the Czech Republic, France, Italy, the Netherlands, Norway, Portugal, the Slovak Republic and Sweden. Estimates based on receiving national direct funding are available for 12 countries: Belgium, Canada, the Czech Republic, France, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, and Sweden. Estimates based on receiving direct funding from international government institutions are available for 8 countries: Belgium, the Czech Republic, France, the Netherlands, Norway, Portugal, the Slovak Republic and Sweden. Table 5 summarises the R&D support policies explored in each country using the first approach (difference-in-differences estimation based on business uptake of support), and information on the sample years covered by the estimation.

Summary statistics for the matched samples used to estimate the effect of R&D tax incentives are shown on a country-by-country basis in Table A.5.

Mean and median employment tend to be similar between treatment and control groups for most countries, especially in view of the relatively large standard deviations. The main exceptions are Belgium and Sweden, where treated firms are larger and perform more R&D. It is also worth noting that the sample firms in France are, on average, much larger than those for other countries and spend more on R&D. For this reason, results for France are reported both for the full sample and for a subsample consisting only of firms in the bottom half of the French R&D distribution. The firms in the sample for Sweden are not particularly large in terms of employment but also spend more on R&D than sample firms for other countries.

Table A.6 presents summary descriptive statistics for the R&D survey samples used in the analysis of direct support. The relatively small numbers of treated firms in many countries (especially Australia and Sweden) reflect the fact that direct support is a more selective tool than R&D tax incentives. The treatment and control firms again look quite similar in most countries.

[21] Note that the treatment and reform dummies enter the equation only in an interaction and not separately, as the firm and time fixed effects absorb the non-interacted dummy variables.

Table 5. Policies explored in the diff-in-diff analysis based on policy uptake

	Policy	Time period
Australia	R&D tax allowance/tax credit	2005-2018
Belgium	Payroll withholding tax exemption, R&D tax credit	2001-2019
Canada	R&D tax credit	2000-2019
Czech Republic	R&D tax allowance	2004-2020
France	R&D tax credit	2001-2014
Italy	R&D tax credit	2013-2019
Netherlands	Payroll withholding tax credit	2013-2019
Norway	R&D tax credit	1999-2021
Portugal	R&D tax credit	2005-2018
Slovak Republic	R&D tax allowance	2011-2021
Sweden	Payroll withholding tax credit	2011-2017
Belgium	National direct funding	2003-2019
Canada	National direct funding	2000-2019
Czech Republic	National direct funding	1999-2021
France	National direct funding	2001-2015
Italy	National direct funding	2007-2019
Japan	National direct funding	1983-2019
Netherlands	National direct funding	2013-2019
New Zealand	National direct funding	2004-2018
Norway	National direct funding	1997-2021
Portugal	National direct funding	1999-2019
Slovak Republic	National direct funding	2009-2021
Sweden	National direct funding	2011-2017
Belgium	Direct funding from abroad	2011-2019
Czech Republic	Direct funding from abroad	2007-2021
France	Direct funding from abroad	2001-2015
Italy	Direct funding from abroad	2007-2019
Netherlands	Direct funding from abroad	2013-2019
Norway	Direct funding from abroad	1997-2021
Portugal	Direct funding from abroad	1999-2019
Slovak Republic	Direct funding from abroad	2009-2021
Sweden	Direct funding from abroad	2011-2017

Notes: Direct funding includes the provision of R&D grants by government and public procurement of R&D services, but it excludes loans and other financial instruments that are expected to be repaid in full.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

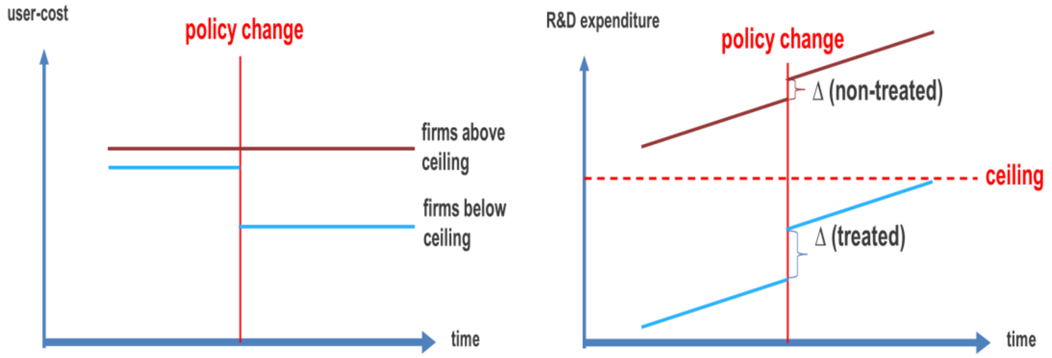
Difference-in-differences based on policy changes

The second approach used for firm-level impact estimation explores the effects of specific R&D tax policy reforms. Since some policy changes often include provisions that imply a differential treatment for different types of firms, it is possible to compare the evolution of R&D expenditure for those groups and interpret the difference as a "treatment effect". The key identifying assumption is that the R&D expenditure of the two groups of firms would evolve along a similar trajectory in the absence of the policy change.

This approach can be illustrated based on the example of the introduction of the SkatteFUNN tax credit in Norway in 2002.[22] Once SkatteFUNN was in place, firms could obtain the R&D tax credit for their R&D expenditure, but only intramural expenditure up to NOK 4 million (about USD 400 000) was eligible. For smaller R&D performers, the change reduced the costs of R&D and served as an incentive for additional R&D spending. However, for firms which already before the policy change regularly invested in R&D more than NOK 4 million, this change increased the amount of tax support they received but did not affect the cost of an *additional* ("marginal") unit of R&D investment and so did not necessarily incentivise additional R&D spending among these firms. To explore the effect of this change in the R&D tax credit policy of Norway, it is instructive to compare how the R&D performance of firms below and above the new expenditure threshold has evolved around the year 2002 (Figure 4).[23]

Figure 4. Difference-in-differences approach to estimating impact of R&D tax incentives

Panel 4A. User cost of R&D before/after policy change   Panel 4B. R&D expenditure before/after policy change



Source: OECD microBeRD.

The comparison of the change in R&D expenditure (or other outcome variable) between the pre-reform and post-reform period for firms below and above the ceiling can be used to estimate the effect of the policy change. Prior to the policy change, firms with R&D expenditure below the (post-reform) expenditure ceiling face a similar user cost of capital as firms above that ceiling (Panel A). The policy change makes the user cost fall for firms below the ceiling. By contrast, firms above the ceiling receive a tax subsidy for their R&D expenditure up to the ceiling, but this does not affect their user cost of an additional (marginal) unit of R&D. If firms' R&D investment depends on their user cost, a fall in the user cost of R&D for firms below the ceiling will lead to increased R&D expenditure for these firms (Panel B).

The comparison of the change in R&D expenditure (or other outcome variable) between the pre-reform and post-reform period for firms below and above the ceiling can be used to estimate the effect of the policy change. Prior to the policy change, firms with R&D expenditure below the (post-reform) expenditure ceiling face a similar user cost of capital as firms above that ceiling (Panel A). The policy change makes the user cost fall for firms below the ceiling. By contrast, firms above the ceiling receive a tax subsidy for their R&D expenditure up to the ceiling, but this does not affect their user cost of an additional (marginal)

[22] Large firms have become eligible for SkateFUNN only in 2003. We ignore this in the illustrative example shown here but reflect it in the estimation.

[23] See Haegeland and Møen (2007) and Bøler, Moxnes and Ulltveit-Moe (2015) for examples of a similar methodology.

unit of R&D. If firms' R&D investment depends on their user cost, a fall in the user cost of R&D for firms below the ceiling will lead to increased R&D expenditure for these firms (Panel B). More formally, the following relationship is estimated:

$$\boldsymbol{logY_{it} = \beta_1 T_i Change_t + \gamma_i + \gamma_t + \varepsilon_{it},} \qquad \text{Equation 13}$$

where Y_{it} is the outcome (e.g. total R&D expenditure) for firm i in year t. T_i marks the time-invariant treatment variable - a binary dummy equal to one for firms affected by the policy change and zero for others. $Change_t$ is a dummy variable equal to zero prior to the policy change and one in the reform year. β_1 is the impact coefficient of interest. The equation controls for time-invariant firm characteristics and year fixed effects. ε_{it} is the residual.[24] Again, the baseline equation no longer controls for firm size, but robustness checks are performed to examine if controlling for firm size would affect the estimated input additionality and innovation effects.

The analysis explores nine policy changes (Table 6). For Norway and Sweden, the estimation is based on the presence of a ceiling on eligible R&D expenditure, whereby the introduction or extension of a tax incentive encourages additional R&D among firms with R&D below but not those with R&D above this ceiling.

In the case of the Netherlands, the estimation exploits the presence of a threshold applicable to total eligible R&D expenditure, where expenditure above the threshold is subject to a reduced tax credit rate. The merger of the payroll withholding tax credit and tax allowance for non-labour related R&D expenses in the Netherlands in 2016 led to an increase in the implied tax subsidy rates for firms below the threshold while leaving them approximately the same for firms above the threshold.

In other cases, policy changes that exclusively apply to firms of different size are exploited. For example, in Japan, a policy change in 2003 made the optional (but more generous) volume-based tax credit also available to large firms (as defined for tax purposes). Previously, these firms could only apply for the incremental R&D tax credit. The differential treatment of firms of different size is also leveraged in Australia, where a policy change in 2012 (introduction of the R&D Tax Incentive, replacing the former R&D tax concession schemes) increased the marginal R&D subsidy rates of SMEs but did not have a material impact on those of large firms.

Whenever tax incentives do not have any design features that imply differences in treatment for specific types of firms, information on the uptake of R&D tax incentives following (or prior to) the policy change is exploited. In other words, a comparison is made between the evolution of R&D expenditure of firms that receive R&D tax incentive support after (or before) the policy change and those that do not.

In other cases, policy changes that exclusively apply to firms of different size are exploited. For example, in Japan, a policy change in 2003 made the optional (but more generous) volume-based tax credit also available to large firms (as defined for tax purposes). Previously, these firms could only apply for the incremental R&D tax credit. The differential treatment of firms of different size is also leveraged in Australia, where a policy change in 2012 (introduction of the R&D Tax Incentive, replacing the former R&D tax concession schemes) increased the marginal R&D subsidy rates of SMEs but did not have a material impact on those of large firms. Relatedly, the estimation for the United Kingdom exploits a 2008 change in

[24] Note that the treatment and change dummies enter the equation only in an interaction and not separately. This is because the firm and time fixed effects absorb the non-interacted dummy variables.

the SME definition, which implied that some firms became eligible for the enhanced R&D tax allowance rates available to SMEs.

Table 6. Policy changes explored in diff-in-diff analysis

	Year of policy reform	Policy change	Treatment definition	Sample years
Ceiling on qualifying R&D expenditure				
Netherlands	2016	Merging of payroll withholding tax credit and tax allowance for non-labour related R&D expenses	Mean total R&D in 2013-2015 < EUR 350 thousand	2013-2019
Norway	2002 (2003)	Volume-based R&D tax credit introduced for SMEs (large firms)	Mean intramural R&D in 1999-2001 < NOK 4 million	1997-2006
Sweden	2014	Introduction of payroll withholding tax credit	Mean R&D tax deduction in 2011-2013 < SEK 2.76 million	2011-2017
Firm size threshold				
Australia	2012	Tax allowance replaced by tax credit with higher rate for SMEs	SME as defined for tax purposes	2008-2016
Japan	2003	Volume-based R&D tax credit extended to large firms	Large firms as defined for tax purposes	2000-2005
SME definition				
United Kingdom	2008	SME definition applicable under the SME R&D tax relief scheme broadened	Employment in 2007 < 500 & sales in 2007 < GBP 100 million	2000-2011
Uptake of R&D tax incentives				
Belgium	2005	Payroll withholding tax exemption introduced	Receives tax relief at least once between 2005 and 2007	2001-2007
France	2008	Hybrid R&D tax credit converted to volume-based R&D tax credit and increase in tax credit rates	Receives tax relief at least once between 2008 and 2012	2004-2012
Italy	2010	Expiration of volume-based R&D tax credit (Law 296/2006), available since 2007	Receives tax relief for qualifying R&D incurred in all years 2007-2009	2007-2013
Norway	2002 (2003)	Volume-based R&D tax credit introduced for SMEs (large firms)	Receives tax relief at least once between 2002 and 2006	1997-2006
Sweden	2014	Introduction of payroll withholding tax credit	Receives tax relief at least once between 2014 and 2017	2011-2017

Note: Australia: SMEs are defined for tax purposes as firms which are not controlled by exempt entities and have turnover of less than AUD 20 million. Due to data limitation, only the turnover-based condition is applied here. Japan: SMEs are defined for tax purposes as firms with 100 million yen or less of stated capital or firms controlled by an enterprise meeting the capital condition. Due to data limitation, only each firm's own stated capital is used here to define SMEs. Norway: Estimation takes into account that large firms became eligible for the tax credit only in 2003. Norway applies separate ceilings on intramural, extramural and total R&D expenditure. The ceiling on intramural expenditure is used here to produce baseline estimates, and robustness of the results to instead using the ceiling on the total R&D expenditure is tested.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, August 2022.

Whenever tax incentives do not have any design features that imply differences in treatment for specific types of firms, information on the uptake of R&D tax incentives following (or prior to) the policy change is exploited. In other words, a comparison is made between the evolution of R&D expenditure of firms that receive R&D tax incentive support after (or before) the policy change and those that do not.[25]

Policy reforms where treated firms are defined by receiving tax support *after* the policy change include the introduction of a partial payroll withholding tax exemption in Belgium in 2005,[26] and the conversion of the previously hybrid R&D tax credit in France to an entirely volume-based tax credit in 2008. This definition of treatment group is also applied for Norway and Sweden (where an alternative treatment group definition based on ceilings are available) to allow a comparison of estimates obtained with different treatment group definitions when studying the same policy change. For Italy, in contrast, the analysis explores the expiration of the volume-based R&D tax credit in 2010, which had been available in Italy since 2007. Treated firms are defined as those that incurred qualifying R&D expenditure and were eligible to receive R&D tax support in the years 2007-2009, i.e. *before* the policy change.[27]

In the estimations exploiting firm size thresholds (Australia, Japan) or expenditure ceilings (Austria, Norway, Sweden) or thresholds (the Netherlands), the sample is restricted to firms that are in the vicinity of the relevant cut-off points. Firms for which the pre-policy change value of the relevant variable (e.g. stated capital, R&D expenditure) is more than 10 times larger than the given threshold/ceiling are excluded from the analysis. In the estimations based on R&D expenditure ceilings, firms are also dropped from the analysis when their pre-policy change level of R&D expenditure differs from the ceiling by less than a factor of 1.3. In this case, it is unclear if firms so close to the ceiling should be considered as treated or not.

Table A.7 presents summary statistics for the firms included in the difference-in-difference analysis based on policy changes. Large differences exist between treatment and control groups, especially when these are defined based on firm size or R&D expenditure. This is to be expected. The key assumption for the estimation is that these differences are not correlated with changes in firms' R&D expenditure following the policy change.

Economic returns to R&D and spillovers

An additional novelty in the analysis carried out in microBeRD+ is the firm level analysis of the returns to business R&D investment. The returns can accrue to the firm investing in R&D (private returns) but the knowledge generated through investment in R&D – potentially non-exclusive and non-rival - may also spill over to other firms (public returns) through multiple channels. The sum of private and public returns from the R&D investment form the social returns t business R&D. Similar to the micro-aggregated analysis

[25] This approach is related to the firm-level difference-in-differences matching analysis based on policy uptake discussed earlier. However, while that analysis observes multiple cohorts of firms starting to use the tax incentives in different years, the estimation discussed here focuses on the initial cohort of R&D tax relief beneficiaries that started to receive R&D tax support following the introduction or major reform of existing R&D tax incentives. For this cohort, the timing of starting to use the tax incentives is largely determined by the policy change and, as such, is less likely to be correlated with some firm-specific time-varying factors that could also be driving R&D performance. Also, the approach discussed here does not make use of matching.

[26] Belgium introduced an R&D tax credit in 2007. The results reported for Belgium (sample period 2001-2007) reflect primarily the effect of the partial exemption rather than tax credit which only had limited uptake in the first years.

[27] The R&D tax credit was extended from 2009 to 2011 but was only available to firms that had incurred qualifying R&D expenditure in 2007-09 and not yet received tax relief.

based on linked microBeRD-MultiProd data, the study estimates a value-added production function given by

$$\mathrm{VA} = \mathrm{A}L^{\beta^L}K^{\beta^K}R^{\beta^{RD}}O^{\beta^O}S^{\beta^S} \quad \textbf{Equation 14}$$

where *A* is the industry total factor productivity, *L* is industry employment, *K* is industry fixed capital stock, *R* is industry's own stock of R&D capital, constructed from annual R&D investment using the perpetual inventory method and depreciation rate of 15%, and *S* is the spillover variable, constructed as the weighted average of the stocks of R&D capital in all industries. Similar to the micro-aggregated analysis, weights used to construct the spillover variable are given by the share of each industry *j* in inputs purchased by a firm *i*'s industry. The shares are measured using country-specific input-output matrices from the OECD Inter-Country Input-Output database. As previously noted earlier for micro-aggregated analysis, this approach captures spillovers from upstream firms to downstream firms, based on the idea that firms are likely to benefit and learn from knowledge created by companies from which they source inputs, but follow-up analysis could also explore spillovers flowing in the opposite direction, from downstream buyers to upstream suppliers.

An important question in the case of estimation at the firm level is how to treat R&D of firms operating in the same industry as firm *i*. While firm *i* can be expected to benefit from knowledge spillovers from other firms in the same industry, at least some of these firms are also likely to be its competitors, and R&D by firm *i*'s competitors may harm firm *i* through business stealing effects. Indeed, distinguishing between knowledge spillover effects and business stealing effects has been one of the major challenges in the literature (see Bloom et al., 2013). The present analysis addresses this challenge by also including R&D capital stock of firms in the same 3-digit industry, S^{own}, in the production function. The elasticity with respect to S^{own}, β^O, captures a mix of negative business stealing effects and positive knowledge spillovers within narrowly defined industries. If these opposite forces cancel out, this elasticity can be expected to be close to zero. In contrast, the elasticity with the spillover variable S^{ext}, β^S, then captures knowledge spillovers from upstream industries.

The production function is estimated at the firm level using the following estimating equation:

$$logVA_{it} = \beta^L logL_{it} + \beta^K logK_{it} + \beta^{RD} logR_{it} + \beta^O logS_{it}^{own} + \beta^S logS_{it}^{ext} + \gamma_i + \gamma_t + \varepsilon_{it} \quad \textbf{Equation 15}$$

β^{RD} is the elasticity of industry value added with respect to the stock of R&D capital, and the implied own-industry return to R&D investment can be calculated as this elasticity divided by the ratio of industry R&D stock to industry value added, $\rho = \frac{\beta^{RD}}{\frac{R}{VA}}$. The returns own-industry R&D and R&D in upstream industries can be defined in an analogous way.

3 Results from the extended analysis of R&D input additionality

This section presents the results of the extended analysis of R&D input additionality based on the two microBeRD methodologies, namely the cross-country analysis of migro-aggregated cell-level data and the country-specific firm-level harmonised regression results for Canada, Italy, the Netherlands, New Zealand and the Slovak Republic.

3.1. Cross-country input additionality analysis

Reassessing the impact of R&D tax incentives on R&D

Effects on overall R&D investment

Table 7 summarises the baseline results from the micro-aggregated impact analysis at country-industry-firm size (cell) level. Coefficients indicate the elasticity of R&D expenditure to the user cost of R&D (B-Index), which represents the percentage change in a cell's total R&D expenditure resulting from a one percentage change in the cell's average B-Index. The outcome variable in all specifications is total intramural R&D expenditure in each cell. Regressions generally include controls for industry-level value added and country-industry-size, industry-year and size-year fixed effects (FE).

With some variation across specifications, estimates based on micro-aggregated R&D survey data imply an overall user cost elasticity of R&D expenditure of -0.6, which is similar to the elasticity found in the initial microBeRD R&D input analysis (OECD, 2020a). The simplest specification, including the contemporary B-Index as policy variable and common year fixed effects while not controlling for industry-level value added yields an elasticity of -0.57 (column 1). The inclusion of industry-year and size-year fixed effects does not appreciably change the35 estimate (column 2), and neither does the inclusion of lagged value added as a control variable (column 3).

When the B-Index is calculated based on R&D expenditure two years earlier ($BIndex_{cist}^{syn2}$), to avoid the potential bias arising from the simultaneity of the *B-Index* and R&D expenditure, the estimated elasticity slightly increases (column 5). This increase is not driven by a change in the sample (observations for which lagged R&D expenditure is not available are dropped), as an estimate based on the reduced sample but a contemporaneous B-Index (column 4) is similar to that found in the initial specification (column 3). These results based on the contemporaneous B-Index are close to other estimates found in the literature and in the previous microBeRD work (OECD, 2020a).

Table 7. R&D price elasticity by measure of user cost – baseline specification

Measure of user cost	Core indicator BIndex			Synthetic BIndexSyn		Adjusted for tax support use - BIndexTax	
Dependent variable: log expenditure on	Intramural						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log BIndex	-0.574***	-0.561***	-0.587***	-0.549***			
	(0.054)	(0.046)	(0.047)	(0.048)			
log BIndexSyn					-0.573***	-0.595***	
					(0.048)	(0.054)	
log BIndexTax							-1.000***
							(0.086)
log Value Added t-2			0.223***	0.190***	0.195***	0.182**	0.228***
			(0.057)	(0.062)	(0.062)	(0.071)	(0.074)
Country-industry-size class FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y						
Industry -Size class-Year FE		Y	Y	Y	Y	Y	Y
Observations	11715	11715	11715	8696	8696	5150	5150
Countries	21	21	21	19	19	12	12

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. The full sample covers 21 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Results in columns 4-5 are based on observations with non-missing values of BIndexSyn and do not include Spain and Switzerland. Results in columns 6-7 are based on observations with matched R&D and tax relief microdata and include Australia, Belgium, the Czech Republic, France, Hungary, Ireland, Italy, the Netherlands, Norway, New Zealand, Portugal and Sweden. Results reported in column 7 are based on an instrumental variables estimation, using $BIndex_{cist}^{syn}$ as an instrument for $BIndex_t^{Tax}$.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Conventional user cost measures may overstate the actual level of support because all firms are assumed to be profitable and able to use earned R&D tax deductions. Provisions for loss-making firms (carry-overs, refunds) do not feed into the modelling of the micro-databased B-Index as it is not possible to identify the baseline tax liability of firms. This may potentially underestimate the price elasticity of R&D. However, the baseline specification can be re-estimated using the tax-support-based version of the *B-Index* indicator ($BIndex_t^{Tax}$), available for a subset of countries with access to R&D tax relief microdata. Since firms' decision to use the tax incentives is endogenous, $BIndex_t^{Tax}$ is instrumented with $BIndex_{cist}^{syn2}$. Accounting for the actual use of R&D tax incentives, the estimated user cost elasticity increases (in absolute value) by about a third and yields a substantially larger elasticity estimate of -1.00 (column 7).This increase is likely explained by the fact that the R&D price elasticity estimated based on $Bindex_{cist}$ or $BIndex_{cist}^{syn2}$ reflects an "intention-to-treat" effect across the firm population, independently of the actual uptake of R&D tax incentives by firms. This can lead to an underestimation of the price elasticity of R&D when only a fraction of firms effectively used R&D tax incentives, and suggests that the existing R&D price elasticities obtained in the literature, which generally do not reflect R&D tax incentive use, might understate the actual price elasticity of R&D.[28]

[28] Labeaga Azcona et al. (2014) discuss the distinction between ex-ante claimable and ex-post claimed tax relief and its impact on the estimated effects of R&D tax incentives.

Table 8 shows the results of two additional robustness checks of the baseline analysis presented above. The first addresses the potential endogeneity of the micro-aggregated B-Index measure through instrumental variable (IV) estimation, instrumenting the average (log) B-Index with a synthetic B-Index measure that captures only policy changes and keeps the set of firms and their R&D expenditure fixed. For reference purposes, column 1 of Table 8 replicates the results of column 3 in Table 7. Column 2 (Table 8) shows that the estimated elasticity remains virtually identical when the data sample is restricted to observations for which it is possible to construct the instrumental variable. Using the IV estimation (column 3), where all variation in the BIndex comes purely from changes in the generosity and design of R&D tax incentives, gives also very similar results to the baseline estimation, with a marginally larger (in absolute value).

Table 8. R&D price elasticity by adjusted measures of user cost

Measure of user cost	BIndex		BIndex Instrumented	BIndex	BIndex Weighted
Dependent variable log R&D expenditure	Intramural				
	(1)	(2)	(3)	(4)	(5)
log BIndex	-0.587***	-0.562***	-0.599***	-0.589***	
	(0.047)	(0.048)	(0.052)	(0.048)	
log BIndexWgt					-0.576***
					(0.049)
Observations	11715	9713	9713	9869	9869
Countries	21	21	21	18	18
F-Value			17125		

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. Results in column 3 are based on an instrumental variables estimation, using $\overline{logBIndex}_{cist}^{syn}$ as instrument for the standard non-weighted B-Index measure. Specification (1), based on the standard non-weighted B-Index measure, and specifications 2 (standard B-Index) and 3 (instrumented B-Index), based on the instrumental variable estimation sample, cover 21 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Results in columns 4-5, based on non-missing observations for the R&D weighted B-Index measure, cover 18 countries, excluding Canada, New Zealand and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

A second check examines the implications of using an *unweighted* average BIndex within a country-industry-size class cell when cell-level R&D performance is disproportionally driven by large R&D performers. The analysis is replicated using an R&D-expenditure weighted average BIndex measure. Restricting the sample to those observations where the weighted average BIndex is available (column 4 of Table 8) leaves the estimated elasticity unchanged, and the estimated elasticity is only marginally reduced when the weighted average BIndex is used in place (column 5 of Table 8) of the unweighted average used in the baseline specification.

To better understand the effects of R&D tax incentives on business R&D expenditure, it is useful to explore their effects for different types of intramural R&D costs (labour, other current expenditure, capital expenditure), intramural R&D (inhouse R&D) vs extramural R&D (outsourced R&D) and the orientation of intramural R&D (research vs. experimental development). The estimates indicate positive effects of R&D tax incentives for all main types of R&D costs (Table 9), but stronger effects are found for capital than for current R&D expenditure. Likewise, the estimates indicate that R&D tax incentives have substantially larger effects on outsourced R&D than R&D performed in-house.

Like the first microBeRD results (OECD, 2020a), the updated results from the cross-country study carried out as part of microBeRD+ point to much stronger effects of R&D tax incentives on experimental development (elasticity of –0.8) compared to research (elasticity of -0.2), suggesting that R&D tax incentives are more effective at boosting R&D closer to market application.

Table 9. R&D price elasticity by type of R&D expenditure

Dependent variable:	**Intramural**	**Labour**	**Other Current**	**Capital**	**Intra -mural**	**Extra-mural**	**Research**	**Experimental development**
log R&D expenditure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log BIndexSyn	-0.534***	-0.483***	-0.396***	-0.874***	-0.520***	-1.838***	-0.230***	-0.812***
	(0.048)	(0.046)	(0.065)	(0.088)	(0.048)	(0.142)	(0.068)	(0.060)
Observations	7860	7860	7860	7860	6352	6352	7237	7237
Countries	17	17	17	17	18	18	16	16

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. The analysis covers 19 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom. Results in column 1 are based on observations Results in columns 1-4 are based on observations with non-missing values of intramural R&D by type of cost and do not include Canada and Ireland. Results in columns 5 and 6 are based on observations with non-missing values of extramural R&D expenditures and do not include Australia. Results in columns 7 and 8 are based on observations with non-missing values of intramural R&D by type of cost and do not include Canada, Hungary and Ireland.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Heterogeneous effects

The micro-aggregated approach adopted allows examining how the price elasticity of R&D varies across firms with different characteristics. Table 10 documents a larger responsiveness among smaller firms to R&D tax incentives in a (micro)-aggregate, cross-country context (column 1). This result is in line with firm-level studies (see Appelt et al. 2016).[29] The estimation includes interactions of the B-Index with dummy variables for medium-sized and small firms. The estimated coefficient for the non-interacted B-Index can be interpreted as the elasticity for the baseline group of large firms.

The heterogeneous effects by firm size depend on the type of R&D cost (Column 2-4). The stronger overall elasticity of intramural R&D expenditure for medium and small firms is driven by current intramural R&D expenditure. Large firms show elasticities for current intramural expenditure that are small (-0.10 for R&D labour and -0.16 for other current R&D expenditure) and not statistically significantly different from zero. In contrast, large firms show relatively strong elasticities for capital intramural expenditure (-0.86) that are not statistically significantly different from those for medium-sized and small firms.

A notable difference between the current and previous microBeRD results (OECD, 2020a) is that the former (Column 5-6) show a much larger elasticity (in absolute value) of extramural R&D expenditure for small and medium firms, whereas the earlier results found no evidence of statistically significant differences in the elasticities of extramural expenditure by firm size.

[29] Larger effects of tax incentives on smaller firms are found by Haegeland and Møen (2007), Baghana and Mohnen (2009), Lokshin and Mohnen (2012), Azcona et al. (2014) and Kasahara, Shimotsu and Suzuki (2014). A meta-analysis by Castellacci and Lie (2015) also indicates stronger effects of tax incentives for SMEs. In contrast, Rao (2016) does not find systematic differences in user cost elasticities across firm size quintiles.

The estimates presented in this paper also provide some new insights into the effect of R&D tax incentives by firm size and orientation of R&D (Column 7-8). While stronger effects are again found for small and medium-sized vs large companies and this for both research and experimental development, the comparatively stronger effect of R&D tax incentives on experimental development vs research appears to hold across all size classes but to proportionally increase in firm size, i.e. it is more pronounced for large companies (elasticity of –0.1 for research and -0.35 for experimental development) compared to medium-sized (elasticity of –0.48 for research and -0.98 for experimental development) and small (elasticity of –0.65 for research and -1.02 for experimental development) companies.

Table 10. R&D price elasticity by firm size and type of R&D expenditure

Dependent variable:	Intramural	Labour	Other Current	Capital	Intra -mural	Extra-mural	Research	Experimental development
log R&D expenditure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log BIndexSyn	-0.166*	-0.100	-0.016	-0.864***	-0.073	-0.446**	0.101	-0.352***
	(0.096)	(0.094)	(0.125)	(0.183)	(0.090)	(0.196)	(0.146)	(0.117)
log BIndexSyn x medium	-0.467***	-0.439***	-0.498***	0.074	-0.517***	-1.345***	-0.378**	-0.627***
	(0.119)	(0.116)	(0.171)	(0.229)	(0.114)	(0.278)	(0.179)	(0.152)
log BIndexSyn x small	-0.663***	-0.631***	-0.565***	-0.100	-0.689***	-2.398***	-0.544***	-0.663***
	(0.118)	(0.114)	(0.155)	(0.228)	(0.117)	(0.275)	(0.177)	(0.143)
Observations	8673	7845	7845	7845	6350	6350	7237	7237
Countries	18	16	16	16	17	17	16	16

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. The analysis covers 18 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom. Results in columns 2-4 are based on observations with non-missing values of intramural R&D by type of cost and do not include Canada and Ireland. Results in columns 5 and 6 are based on observations with non-missing values of extramural R&D expenditures and do not include Australia. Results in columns 7 and 8 are based on observations with non-missing values of intramural R&D by type of cost and do not include Canada and Ireland.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

The overall greater responsiveness of R&D investments conducted by small firms to R&D tax incentives could be related to the relatively low amount of R&D these firms perform on average, compared to large firms. It is also possible that firms in more R&D-intensive industries systematically differ in their response to tax incentives. The analysis presented in Table 11 explores these hypotheses, replicating the analysis carried out in (OECD, 2020a) based on updated micro-data. The first specification reproduces the results in column 1 of Table 10, showing greater elasticities for small and medium-sized firms as compared to large firms.

The next specification (column 2) interacts the B-Index with the log intramural R&D expenditure of an average firm within each country-industry-size cell (measured in the first year when that cell appears in the data) instead of employment size dummies. The interaction term is normalised in such a way that the coefficient on the non-interacted B-Index captures the effect on data cells with the sample mean level of average R&D expenditure (about USD 1 million) and the estimated coefficient on the interaction term corresponds to a 1-standard-deviation change in the average R&D expenditure. The results suggest that the group of firms with a greater (initial) R&D expenditure is on average less responsive to R&D tax incentives. This effect is strong in economic terms. The estimates indicate that a country-industry-size class cell with average R&D expenditure that is one standard deviation above the sample mean (about USD 5 million) has a user cost elasticity close to zero, while a country-industry-size class cell with average

R&D expenditure one standard deviation below the sample mean (about USD 200,000) has a user cost elasticity of over one in absolute terms.

Table 11. R&D price elasticity by firm size and initial R&D intensity

Interaction	By firm size	By average R&D expenditure		By firm size and average R&D expenditure	
Dependent variable: log R&D expenditure	(1)	(2)	(3)	(4)	(5)
log BIndexSyn	-0.166*	-0.603***	-0.083	-0.758***	-0.066
	(0.096)	(0.043)	(0.079)	(0.124)	(0.087)
log BIndexSyn x medium	-0.467***			0.146	-0.072
	(0.119)			(0.143)	(0.157)
log BIndexSyn x small	-0.663***			0.266	0.073
	(0.118)			(0.169)	(0.193)
log BIndexSyn x initial average R&D		0.284***		0.337***	
		(0.028)		(0.045)	
log BIndexSyn x medium initial average R&D			-0.590***		-0.586***
			(0.107)		(0.158)
log BIndexSyn x low initial average R&D			-0.884***		-0.952***
			(0.115)		(0.191)
Observations	8673	8673	8673	8673	8673
Countries	18	18	18	18	18

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. Initial average R&D is defined as average intramural R&D expenditure by firms in given country-industry-size class cell in the first year of observation; it is classified medium if it is between USD 400 000 and 2 000 000 and low if it is below USD 400 000. The analysis covers 18 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Ireland, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom. Results in columns 2-3 are based on observations with matched R&D and tax relief microdata and include Australia, Belgium, the Czech Republic, France, Ireland, Italy, the Netherlands, Norway, New Zealand, Portugal and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Instead of interacting the B-Index with the initial average level of R&D expenditure as a continuous variable, column 3 interacts it with dummy variables that are defined by partitioning all country-industry-size class cells into three similarly sized groups based on the initial average level of intramural R&D expenditure across firms within each cell. This alternative specification (column 4) again indicates that firms' responsiveness to R&D tax incentives decreases with the initial level of R&D performance. While for firms with a high average level of intramural R&D expenditure (above USD 2 million) the estimated elasticity is not statistically significant from zero, firms with a medium (between USD 400 thousand and USD 2 million), and in particular those with a low (below USD 400 thousand), average level of R&D expenditure are found to respond more strongly to R&D tax incentives. The R&D price elasticities of firms with a medium and low level of R&D expenditure are estimated at -0.59 and -0.88 respectively.

When the interactions of the B-Index with firm size dummies and initial average R&D expenditure (level specification) are all included (column 4), the estimated interactions with size dummies become small and cease to be statistically significant, while the estimated interaction with initial average R&D expenditure retains high statistical significance and slightly increases in size. The results are similar when dummies for initial average R&D are used instead of a continuous variable (column 5). This result suggests that firms' responsiveness to R&D tax incentives is determined by firms' initial level of R&D expenditure – the group of firms that performs relatively little R&D in the absence of tax incentives increases its R&D expenditure most (in proportional terms). In other words, the observed variation in the price elasticity of R&D across firms of different size seems to reflect firms' level of R&D performance rather than firm size as such. The greater user cost elasticity – and, by implication, greater input additionality (Table 14.) – estimated for smaller firms, is a consequence of the fact that small firms perform less R&D on average. The results of the analysis of the heterogeneity of business responses to R&D tax incentives are effectively robust to the data update and in line with the results presented in (OECD, 2020a).

The results by firm size and initial R&D expenditure are qualitatively similar but show larger elasticities when the estimation takes into account whether firms actually use R&D tax support (Table 12). They confirm the previous observation that the initial level of R&D spending, rather than firm size, drives the heterogeneity in results and that it is important to account for the actual use of R&D tax incentives by firms in order not to overstate the actual level of support and underestimate the price elasticity of R&D when only a fraction of firms effectively used R&D tax incentives. More specifically, they indicate user cost elasticities of -0.2 (statistically insignificant) for firms with large initial R&D expenditure but about -1.0 for firms with medium initial R&D expenditure and -1.5 for firms with low initial R&D expenditure.

Table 12. R&D price elasticity by firm size and initial R&D intensity accounting for R&D tax support use

Interaction	By firm size	By average R&D expenditure		By firm size and average R&D expenditure	
Dependent variable: log R&D expenditure	(1)	(2)	(3)	(4)	(5)
log BIndexTax	-0.215	-0.965***	-0.171	-1.599***	-0.141
	(0.197)	(0.078)	(0.147)	(0.266)	(0.185)
log BIndexTax x medium	-0.831***			0.570*	-0.137
	(0.229)			(0.294)	(0.32)
log BIndexTax x small	-1.029***			0.997***	0.363
	(0.227)			(0.339)	(0.375)
log BIndexTax x initial average R&D		0.488***		0.693***	
		(0.058)		(0.095)	
log BIndexTax x medium initial average R&D			-0.861***		-0.923***
			(0.176)		(0.274)
log BIndexTax x low initial average R&D			-1.364***		-1.706***
			(0.208)		(0.332)
Observations	5770	5770	5770	5770	5770
Countries	12	12	12	12	12

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. Initial average R&D is defined as average intramural R&D expenditure by firms in given country-industry-size class cell in the first year of observation; it is classified medium if it is between USD 400 000 and 2 000 000 and low if it is below USD 400 000. The analysis covers 13 OECD countries: Australia, Belgium, the Czech Republic, France, Germany, Ireland, Israel, Italy, the Netherlands, New Zealand, Norway, Portugal and Sweden. Results in columns 2-3 are based on observations with matched R&D and tax relief microdata and include Australia, Belgium, the Czech Republic, France, Ireland, Italy, the Netherlands, Norway, New Zealand, Portugal and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

The role of R&D tax incentives in the policy mix

An important policy question is how the effectiveness of R&D tax incentives compares to that of alternative policy tools and how the various policy tools available to policymakers interact with each other. This section presents the results of an exploratory analysis on the role of the innovation policy mix, focusing on direct R&D funding as well as R&D tax incentives. Leveraging updated microdata and data for a broader set of countries, this analysis aims to reassess the preliminary findings obtained in the initial analysis of this kind carried out in the first stage of the project (OECD, 2020a).

Table 13 and Table 14. provide the updated results on the role of direct funding of business R&D. To address the potential endogeneity of direct support, own-funded intramural R&D expenditure is used as outcome variable (i.e. intramural R&D expenditure net of direct funding and other external sources of R&D funding) and a two-year lag of the direct funding is used in the estimation.

The first estimation (column 1) includes only the synthetic B-Index as a policy variable. The user cost elasticity, estimated at around – 0.69, is similar to the one found in the initial analysis on the price elasticity of intramural R&D based on the data for the full sample of 18 countries (Table 7, column 5). The elasticity of own-funded intramural R&D with respect to direct funding (column 2) is 0.041, implying that a 10% increase in direct funding corresponds to an R&D increase of around 0.41%. The elasticity of tax support remains virtually unchanged when effects of both types of support are estimated simultaneously, while the elasticity for direct support decreases slightly to 0.034 (column 3).

Table 13. R&D price elasticity by R&D support policy instrument

Policy variable	Tax	Direct	Both	Interaction	By firm size
Dependent variable:	Own-funded intramural R&D				
log R&D expenditure	(1)	(2)	(3)	(4)	(5)
log BIndexSyn	-0.614***		-0.602***	-0.595***	-0.257***
	(0.051)		(0.051)	(0.050)	(0.099)
log Direct Funding (2-year lag)		0.043***	0.037***	0.036***	0.035***
		(0.008)	(0.008)	(0.008)	(0.008)
log BIndexSyn x log (Direct				-0.124***	-0.066*
Funding / initial R&D)				(0.041)	(0.039)
log BIndexSyn x medium (50-249 emp.)					-0.341***
					(0.123)
log BIndexSyn x small (10-49 emp.)					-0.582***
					(0.123)
Observations	7035	7035	7035	7035	7035
Countries	17	17	17	17	16

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. The analysis covers 17 OECD countries: Australia, Austria, Belgium, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

To test for the complementarity/substitutability between the two types of R&D support, the B-Index is interacted with direct funding (column 4). In calculating this interaction, direct support is normalised by the level of intramural R&D expenditure by firms in a given country-industry-size class group. This ensures that the interaction term captures the intensity of direct support and not just the number of firms in that country-industry-size class cell. The estimated interaction effect is negative and strongly statistically significant, implying that the price elasticity of R&D increases with the intensity of direct funding. The estimate suggests that country-industry-size class cells with an intensity of direct funding one standard deviation above the sample mean have a user cost elasticity that is about 0.12 (21%) greater in magnitude than the elasticity of firms in the mean data cell. This preliminary finding suggests that R&D tax incentives and direct funding have a complementary, mutually reinforcing effect. One issue with the estimates in column 4 is that if smaller firms receive a disproportional share of direct funding, the interaction with high intensity of direct funding could simply be capturing the differential effects by firm size. For this reason, column 5 shows the results of an estimation that additionally includes interactions of the synthetic B-Index measure with size class dummies. As a result of this change, the interaction term between tax incentives and direct funding is reduced by about a half, but remains statistically significant and economically meaningful.

The evidence base on the interaction between direct funding and tax support is comparatively scarce and rather mixed (Appelt et al., 2016). While a number of studies find evidence of a substitution effect (Montmartin and Herrera, 2015; Dumont, 2017), others (Bérubé and Mohnen, 2009; Falk et al., 2009) yield results that speak in favour of a complementarity between R&D tax incentives and direct funding or a neutral effect (Lhuillery et al., 2014). Recent research suggests that the complementarity effect found for R&D tax incentives and direct funding in this cross-country analysis may be mainly driven by small firms (Huergo and Moreno, 2017; Pless, 2022). Using funding rules and policy changes in a quasi-experimental evaluation, Pless (2022), for instance, shows that direct grants and tax credits are complements for small firms but substitutes for larger firms. Huergo and Moreno (2017) yield a similar result for multiple programme participation in Spain (subsidies and R&D loans): multiple schemes are found to have a larger impact on the R&D performance of SMEs, whereas a crowding out effect cannot be ruled out for large firms. An extended analysis would be required to explore this in more detail.

Incrementality ratios

Incrementality ratios can be derived based on the estimated elasticities of business R&D to the user cost (B-Index). These ratios indicate the extent to which R&D support policies are effective in generating additional R&D expenditure beyond the counterfactual level that would have been observed in their absence. Table 14 presents the incrementality ratios derived for R&D tax incentives based on the main elasticity estimates presented in the previous subsections. Reported are *gross* incrementality ratios. Gross incrementality ratios of less than 1 suggest a crowding out of privately-funded R&D, while those larger than 1 imply crowding-in of privately funded R&D. An incrementality ratio of 1 implies a neutral effect, i.e. one unit of support translates into one unit of R&D.

The baseline specification yields an incrementality ratio of 0.87, implying that one unit of R&D tax subsidy translates into just short of one unit of R&D investment by business. The 90% confidence interval (CI90) for the incrementality ratio is 0.77-0.98. When R&D price elasticities are estimated based on the tax-based version of the B-Index (BIndexTax), which accounts for the actual use of R&D tax incentives, the incrementality ratio increases to 1.37 (CI90 1.22-1.51).

R&D input elasticity estimates by firm size classes indicate a significant but not complete crowding out effect in the case of large firms (IR 0.28, CI90 0.01-0.52), a neutral effect for medium-sized firms (IR 0.95, CI90 0.79-1.09) and crowding in in the case of small firms (IR 1.18, CI90 1.05-1.30). When the estimation accounts for the actual use of R&D tax incentives, the incrementality ratios increase but still point to a crowding out effect in the case of larger firms (IR 0.35, CI90 -0.20-0.83), while a crowding in effect is estimated for medium sized (IR 1.42, CI90 1.21-1.62) and small companies (IR, 1.62, CI90 1.44-1.79). This differential effect is attributable to the initial level of R&D performance rather than firm size as such. For groups with a high initial level of intramural R&D expenditure on average (above USD 2 million), the gross incrementality ratio is estimated at 0.14 (crowding out), while it is 1.00 (neutral) and 1.32 (crowding in) for firm groups with a medium (USD 400 000 - USD 2 million) and low (below USD 400 000) level of average intramural R&D expenditure. When the estimation accounts for the actual use of R&D tax incentives, the incrementality ratios increase but still point to a crowding out effect in the case of groups with a high initial level of intramural R&D expenditure (IR 0.28, CI90 -0.12-0.65), while a crowding in effect is estimated for firm groups with a medium (IR 1.41, CI90 1.22-1.59) and low (IR, 1.84, CI90 1.63-2.03) level of average intramural R&D expenditure.

Table 14. R&D input additionality

	R&D input additionality	Price elasticity estimate	
	Incrementality ratio (gross)	Coefficient	Observations
Tax incentives			
Baseline			
All firms	**0.872** (0.765, 0.974)	-0.573	8696
All firms (accounting for R&D tax support use)	**1.371** (1.220, 1.512)	-1.000	5150
By firm size			
Large (250 or more employees)	**0.277** (0.012, 0.524)	-0.166	8673
Medium (50-249 employees)	**0.946** (0.794, 1.091)	-0.633	8673
Small (10-49 employees)	**1.181** (1.050, 1.304)	-0.829	8673
Large (250 or more employees, accounting for R&D tax support use)	**0.354** (-0.195, 0.825)	-0.215	5770
Medium (50-249 employees, accounting for R&D tax support use)	**1.423** (1.209, 1.621)	-1.039	5770
Small (10-49 employees, accounting for R&D tax support use)	**1.619** (1.435, 1.788)	-1.322	5770
By initial level of R&D of average firm			
Low (< USD 400 000)	**1.319** (1.173, 1.456)	-0.967	8673
Medium (USD 400 000 - 2 000 000)	**1.001** (0.854, 1.141)	-0.673	8673
High (> USD 2 000 000)	**0.141** (-0.082, 0.352)	-0.083	8673
Low (< USD 400 000, accounting for R&D tax support use)	**1.842** (1.633, 2.029)	-0.171	5770
Medium (USD 400 000 - 2 000 000, accounting for R&D tax support use)	**1.410** (1.217, 1.588)	-1.032	5770
High (> USD 2 000 000, accounting for R&D tax support use)	**0.282** (-0.123, 0.648)	-1.534	5770

Note: The table reports incrementality ratios implied by the estimate elasticities of intramural R&D expenditure with respect to $BIndex_t^{syn2}$ and $BIndex_t^{Tax}$, as reported in Table 7, Table 11 and Table 12. in this report. The derivation of the incrementality ratios is described in (OECD, 2020a). Lower and upper limits of the 90% confidence interval are reported in parentheses.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 15 presents the *gross* incrementality ratios for tax support and direct support derived based on the elasticity estimates (average effect across all firms) presented in Table 11**.** The *gross* incrementality ratio of close to 1 estimated for R&D tax incentives is in line with the initial estimates obtained based on the full data set. For direct funding, the *gross* incrementality ratio is estimated at 1.48 (90% confidence interval 1.30-1.66), suggesting that direct funding induces some additional R&D spending by firms beyond the amount of support provided.

Table 15. R&D input additionality by policy instrument

	R&D input additionality	R&D price elasticity	
	Incrementality ratio (gross)	Coefficient	Observations
Analysis of R&D support policy mix (Table 13.)			
R&D tax incentives (all firms)	**0.916** (0.804, 1.024)	-0.602	7035
Direct funding (accounting for receipt of direct funding, 2-year lag)	**1.480** (1.304, 1.657)	0.037	7035
Analysis of R&D tax incentives (Table 7)			
R&D tax incentives (accounting for partial R&D tax incentive uptake)	**1.371** (1.220, 1.512)	-1.000	5150

Note: The table reports incrementality ratios implied by the estimated elasticities of own-funded intramural R&D expenditure with respect to BIndexSyn and direct funding of BERD (Table 13. , column 3). It also includes the incrementality ratios implied by the estimated elasticity of intramural R&D expenditure with respect to BIndexTax (Table 7). The derivation of the incrementality ratios is described in (OECD, 2020a). Lower and upper limits of the 90% confidence interval are reported in parentheses.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

While these results could suggest that direct support measures have on average a larger R&D input additionality than R&D tax incentives, it is important to keep in mind that the estimation based on BIndexSyn yields an "intention to treat" effect which might understate the actual price elasticity of R&D and input additionality of R&D tax incentives. BIndexSyn reflects the generosity of R&D tax incentives in account of firms' characteristics but it does not reflect whether firms actually use tax relief or not. By contrast, direct funding reflects the incidence of direct funding, i.e. it accounts for firms that receive direct funding and those that do not. This asymmetry in measurement warrants attention. The first part of the analysis that focused solely on R&D tax incentives showed that the incrementality ratio estimated for R&D tax incentives increases to 1.37 once the tax-based version of the *B-Index* (BIndexTax), accounting for the actual uptake of R&D tax incentives, is used in the estimation.

While an estimation based on the refined, tax support based *B-Index* indicator is only possible for 11 countries where matched R&D and tax relief microdata are available, it suggests that the R&D input additionality of R&D tax incentives is likely larger that it would seem when not accounting for tax incentive use and on average not much lower than the R&D input additionality of direct funding.

R&D tax incentive design and business responsiveness to R&D tax support

This section explores how the user cost elasticity of R&D is linked to key R&D tax incentive design features. Table 16 displays the results of an exploratory analysis where each design feature is interacted with the log B-Index. In columns 1-6, one design feature is considered at a time, while in column 8, all interactions are included. The average estimated elasticity on the restricted sample (observations with active tax incentives) without any interactions is -0.49, which is slightly smaller than the baseline estimate of -0.57 reported in column 5 of Table 7.

The availability of a refund provision could increase the effectiveness of R&D tax incentives in raising business R&D because it allows loss-making firms to benefit from the incentive with certainty and within a close time window after they perform R&D, rather than only years later once they become profitable. This could make a large difference especially for young firms which seldom generate sufficient profits in their initial years of existence. The estimates in columns 2 and 8 of Table 16 are in line with this conjecture, indicating an elasticity that is nearly twice as large when a refund provision is in place compared to the counterfactual scenario.

Some countries offer R&D tax incentives that are redeemable against payroll (e.g. withholding) taxes or social security contributions instead of corporate income taxes. Like refund provisions, wage tax related incentives benefit loss-making firms. While limited to the payroll tax and social security liability of the corresponding tax period, unless alternative restrictions apply, such incentives are disconnected from the corporate tax liability of the firm and thus in principle payable in both profit and loss-making scenarios. As payroll taxes are also payable at more frequent basis – typically on a quarterly basis – such incentives allow for quicker and more regular tax relief payments than corporate tax offsets. For these reasons, payroll tax offsets may have a bigger effect on business R&D expenditure than other corporate tax offsets. The estimates in columns 3 and 8 of Table 15 offer some evidence of this being the case, showing an approximately three times larger elasticity in the case of R&D tax incentives that are redeemable against payroll taxes or social security contributions.

By contrast, a limitation of qualifying R&D expenditure through an upper ceiling or threshold (beyond which a reduced rate of R&D tax relief applies) could make the extent to which businesses respond to R&D tax incentives (R&D elasticity) smaller. The micro-aggregated B-Index reflects the reduced rate of R&D tax subsidy above the ceiling or threshold. However, measures of marginal tax subsidy rates such as those based on the B-Index apply to one additional unit of R&D but not full-scale R&D projects. Firms may be subject to a positive/high marginal R&D tax subsidy rate for one additional dollar of R&D expenditure, but the average subsidy for a completely new R&D project may be much lower if a significant part of R&D is subject to the zero (ceiling) or reduced (threshold) R&D tax subsidy rate. This would, in particular, reduce the estimated elasticity for firms with R&D expenditure just below the ceiling or threshold. Overall, across firms of all sizes, the preliminary estimates (Table 16, in columns 4 and 8) do not indicate that the presence of a ceiling or a threshold reduces the estimated R&D elasticity.

The type of tax instrument (tax allowance vs tax credit) and the availability of preferential relief provisions for SMEs (e.g. entail enhanced tax credit/allowance rates or other more favourable terms) are two additional, common R&D tax incentive design features, but it is ex-ante not necessarily obvious why the provision of tax relief in form of a tax credit vs. allowance should be associated with either a stronger or reduced R&D elasticity. The results in columns 4, 6 and 8 indeed confirm that there is no difference in the R&D elasticity when differences in such design features apply.

Finally, an important characteristic of an R&D tax incentive is whether all R&D expenditure is subsidised (volume-based incentive) or whether the support only concerns expenditure beyond some pre-defined base amount (incremental incentive), often calculated as a rolling average of R&D expenditures in previous years (Appelt et al, 2016). Policy makers can be inclined to implement incremental incentives on the expectations that this will improve additionality, but this is not necessarily the case. Incremental tax incentives may be associated with a weaker elasticity because current R&D investment increases the base amount and reduces the amount of R&D qualifying for tax relief in the future. However, the evidence in Table 16 is not indicative of such an effect (columns 7 and 8).

Table 16. R&D price elasticity by design feature

Design feature	None	Refund	Payroll	Limitation	Preferential treatment of SMEs	Allowance	Incremental/ Hybrid	All
Reflected in B-index	-	No	Yes	Yes	Yes	Yes	Yes	-
Dependent variable: log R&D expenditure	Intramural							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log BIndexSyn	-0.489***	-0.327***	-0.489***	-0.513***	-0.494***	-0.474***	-0.479***	-0.325**
	(0.055)	(0.108)	(0.055)	(0.058)	(0.055)	(0.055)	(0.080)	(0.127)
log BIndexSyn x refund		-0.201*						-0.268**
		(0.110)						(0.126)
Log BindexSyn x payroll			-0.988*					-0.997*
			(0.518)					(0.535)
log BIndexSyn x limit				0.075				0.028
				(0.065)				(0.081)
log BIndexSyn x prefSME					0.139			0.237
					(0.166)			(0.172)
log BIndexSyn x allowance						-0.263		-0.392
						(0.266)		(0.285)
log BIndexSyn x incremental							-0.058	0.070
							(0.092)	(0.129)
log BIndexSyn x hybrid							-0.112	-0.145
							(0.112)	(0.112)
Observations	7296	7296	7296	7296	7296	7296	7296	7296
Countries	17	17	17	17	17	17	17	17

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects and industry-size class-year fixed effects. The estimation covers 17 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Hungary, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

3.2. Country-specific firm level analysis of R&D input additionality

This section presents the new results from the firm-level impact estimation carried out as part of the extended R&D input additionality analysis in microBeRD+. New firm-level results have been produced for Canada, Italy, the Netherlands, New Zealand, the Slovak Republic and the United Kingdom.

Table 17 shows the results for Canada where the impact of R&D tax incentives and direct funding are estimated using the diff-in-diff methodology, examining firms that start using a given type of public support. Columns 1-3 display the results for R&D tax incentives. They indicate a positive impact of tax incentives on intramural R&D expenditure and on R&D employment, but not on extramural R&D expenditure. Columns 4-5 explore the effects of direct support, and they offer evidence of positive effects of direct funding on intramural R&D expenditure, R&D employment and also extramural R&D expenditure. The results for intramural R&D imply an incrementality ratio of 0.9 in the case of R&D tax incentives and 1.9 in the case of direct government funding.

Table 17. Diff-in-diff estimates of the impact of R&D tax and direct support, Canada

	Tax incentives			Direct support		
Estimation	**DiD based on policy uptake**			**DiD based on policy uptake**		
Dependent variable (log)	**Intramural R&D**	**R&D employment**	**Extramural R&D**	**Intramural R&D**	**R&D employment**	**Extramural R&D**
	(1)	(2)	(3)	(4)	(5)	(6)
ATT	0.229***	0.118***	-0.008	0.208***	0.160***	0.149***
	(0.056)	(0.039)	(0.118)	(0.016)	(0.015)	(0.037)
N (firms-years)	7770	7360	2980	7770	7360	2980
Implied incrementality ratio	0.89			1.89		

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 18 shows the results for Italy. Columns 1-3 replicate the previous analysis for Italy (OECD, 2020a). This estimation exploits the differential impact of repeal of the volume-based R&D tax credit in Italy in 2010 on firms that were or were not using this incentive. The results indicate a negative estimated impact of the tax credit abolition on intramural R&D expenditure and R&D employment, implying a *positive* impact of the R&D tax incentive. The coefficient for extramural R&D expenditure is also negative but not statistically significant. The results for intramural R&D implies a relatively moderate incrementality ratio of 0.6, similar to previous estimates for Italy shown in OECD (2020a).

Columns 4-6 display the results of a new analysis of the impact of the incremental R&D tax credit in Italy over the period 2015-2019. This analysis points out to positive effects on intramural R&D expenditure, R&D employment, and extramural R&D expenditure. However, the implied incrementality ratio obtained for the more recent tax credit scheme is 2.2, more than three times as large as that obtained for the earlier scheme.

Table 18. Diff-in-diff estimates of the impact of R&D tax support, Italy

Volume-based tax credit (2007-09) and incremental R&D tax credit (2015-19)

Policy	Tax incentive 2007-2009			Tax incentive 2015-2019		
Estimation	DiD based on policy change			DiD based on policy uptake		
Dependent variable (log)	Intramural R&D	R&D employment	Extramural R&D	Intramural R&D	R&D employment	Extramural R&D
	(1)	(2)	(3)	(4)	(5)	(6)
ATT	-0.061*	-0.101***	-0.050	0.389***	0.279***	0.144**
	(0.032)	(0.025)	(0.142)	(0.016)	(0.009)	(0.060)
N (firms-years)	19181	18291	5347	90371	89128	24512
Implied incrementality ratio	0.59			2.24		

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 19 presents the results for the Netherlands, both for R&D tax incentives (columns 1-6) and direct funding (columns 7-9). The estimation in columns 1-3 exploits the 2016 merger of the payroll withholding tax credit (WBSO) and the former RDA scheme, which was coupled with an increase in the R&D expenditure threshold (beyond which a reduced WBSO rate applies).

Table 19. Diff-in-diff estimates of the impact of R&D tax and direct support, Netherlands

	Tax incentives					
Estimation	DiD based on a policy change			DiD based on policy uptake		
Dependent variable (log)	Intramural R&D	R&D employment	Extramural R&D	Intramural R&D	R&D employment	Extramural R&D
	(1)	(2)	(3)	(4)	(5)	(6)
ATT	0.192***	0.129***	0.266**	0.577***	0.317**	0.824**
	(0.044)	(0.04)	(0.123)	(0.158)	(0.145)	(0.37)
N (firms-years)	5989	5916	2068	1501	1143	783
Implied incrementality ratio	2.49			3.07		
	Direct support					
Estimation	-	-	-	DiD based on policy uptake		
Dependent variable (log)	-	-	-	Intramural	R&D emp.	Extramural
	-	-	-	(7)	(8)	(9)
ATT	-	-	-	0.255***	0.144***	0.368***
	-	-	-	(0.066)	(0.051)	(0.139)
N (firms-years)	-	-	-	12061	11581	5132
Implied incrementality ratio	-	-	-	1.05		

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Estimates in columns 4-6 rely on an alternative estimation strategy, comparing, over time, firms that did and did not start using the R&D tax incentives. Both methods lead to large and statistically significant estimated effects on intramural R&D expenditure, R&D employment and extramural R&D expenditure. The latter approach implies a large incrementality ratio of around 3. For the earlier approach, the implied incrementality ratio amounts to 2.5 and is of a similar magnitude. Columns 7-9 show the results for direct support, based on a similar methodology as the estimates for tax incentives in columns 4-6. Like R&D tax incentives, direct funding is found to have a positive effect on intramural R&D expenditure, R&D employment and extramural R&D expenditure. However, the incrementality ratio implied for direct support, estimated at around 0.9, is smaller than that for R&D tax incentives.

New exploratory estimates for New Zealand are displayed in Table 20. The estimation examines firms that start using a given type of public support within a diff-in-diff setting. A major limitation of the analysis for R&D tax incentives (columns 1 and 2) is that the data cover only the first year after the introduction of the R&D tax incentive in 2019. Indeed, the results do not indicate any effects of the tax incentive, but this may well be due to a lag between the introduction of the incentive and firms increasing their R&D expenditure. It will, thus, be important to redo the present analysis when newer data becomes available. Results for the impacts of direct support are displayed in columns 3 and 4, and they mimic the findings shown in OECD (2020a).

Table 20. Diff-in-diff estimates of the impact of R&D tax and direct support, New Zealand

	Tax incentives		Direct support	
Estimation	DiD based on policy uptake			
Dependent variable (log)	Intramural R&D	R&D employment	Intramural R&D	R&D employment
	(1)	(2)	(3)	(4)
ATT	-0.036	0.049	0.504***	0.297***
	(0.126)	(0.100)	(0.096)	(0.073)
N (firms-years)	897	870	3228	3090
Implied incrementality ratio	-		-	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 21 shows new results for the Slovak Republic. Like the analysis for New Zealand, the estimates for both tax and direct support compare firms that start using a given type of support to a control group of firms that do not, in a diff-in-diff setting. The results indicate a positive effect of both tax incentives and direct support on the R&D activity of firms, whether measured by R&D expenditure or R&D employment. The estimates imply that 1 EUR of public support induces about 1.4 EUR of additional R&D expenditure in the case of the tax support and 0.75 EUR in the case of direct support.

Table 21. Diff-in-diff estimates of the impact of R&D tax and direct support, Slovak Republic

	Tax incentives		Direct support	
Estimation	DiD based on policy uptake			
Dependent variable (log)	Intramural R&D	R&D Employment	Intramural R&D	R&D employment
	(1)	(2)	(3)	(4)
ATT	0.192**	0.261***	0.252*	0.262**
	(0.095)	(0.076)	(0.131)	(0.108)
N (firms-years)	2320	2318	1893	1892
Implied incrementality ratio	1.44		0.75	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 22 presents new results for the United Kingdom. The estimation of the impact of R&D tax support exploits the 2008 change in the SME definition applicable under the SME R&D tax relief scheme in the United Kingdom. The broadening of this definition implied that certain firms now qualified as SMEs and could benefit from the higher tax allowance rates available to SMEs. The estimated effect of R&D tax incentives is not statistically significant, but it is positive and implies that 1 EUR of public support induces about 1.5 EUR of additional R&D expenditure. In terms of order of magnitude, this effect is not too far from the effect found by Guceri and Liu (2019), yet somewhat smaller than the effect found by Dechezleprêtre et al. (2023). Like microBeRD, both studies exploited the 2008 change in the SME definition applicable under the SMR R&D tax relief scheme yet relied on administrative R&D tax relief rather than business R&D survey microdata.

Table 22. Diff-in-diff estimates of the impact of R&D tax support, United Kingdom

	Tax incentives
Estimation	**DiD based on policy change**
Dependent variable (log)	**Intramural R&D**
	(1)
ATT	0.109
	(0.072)
N (firms-years)	2868
Implied incrementality ratio	1.50

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

4 Results from pilot analysis of R&D output additionality and spillovers

This section presents the findings from the pilot analysis of R&D output additionality and R&D spillovers. The R&D output additionality analysis assesses the innovation and economic effects of R&D tax incentives and direct funding. As discussed in Appelt et al. (2016), a measured increase in R&D expenditure (i.e., R&D input additionality) might not translate into an increase in innovation or economic performance (i.e., R&D output additionality) for several reasons:

- **Re-labelling of existing activities.** Following the introduction of a tax incentive, firms might re label in their accounts and responses to statistical offices some of their ongoing activities (R&D or non R&D related) as R&D investment. This would lead to a spurious increase in measured R&D (see Box 1). The available evidence suggests that the incidence of this factor is relatively small, particularly in the long term.
- **Input price rise.** The introduction of an R&D tax incentive may cause an increase in the wages of scientists and engineers due to their inelastic supply, in particular in the short run. Part of the measured increase in R&D expenditure would then reflect changes in prices rather than volumes of performed R&D.
- **Heterogeneous impacts.** The additional projects financed through R&D tax incentives might be those with the lowest marginal productivity. If there are decreasing marginal returns to R&D, the additional R&D induced by an R&D tax incentive will be less productive than the R&D that would be done even without the incentives. The broader socioeconomic impact of R&D tax incentives may further depend on the type of firm performing R&D. A recent study by Bloom et al. (2013), for instance, suggests that smaller firms generate lower social returns to R&D because they operate more in technological niches.

The evaluation of R&D output additionality is also complicated by several challenges. Firstly, the available measures of innovation output are highly imperfect. Secondly, the lag between R&D investments and the resulting innovations varies widely and can be very long. Thirdly, the benefits of the incentives might spill over to firms that did not directly receive any support, complicating estimation based on comparison of recipient and non-recipient firms. Finally, innovations brought about by R&D tax incentives schemes might differ from innovations funded by firms or by government grants.

The evaluation of the economic impact of R&D tax incentives and direct government funding in turn entails an assessment of the economic returns to business R&D and spillovers. Challenges in the measurement of R&D inputs, economic output and productivity and the spillovers arising from business R&D investment aggravate the estimation of the private returns to R&D and R&D benefits that accrue to society.[30]. As discussed in the OECD microBeRD+ conference of September 2022, the measurement of knowledge spillovers is still in its infancy and there is no "gold standard" approach to it. The size of

[30] For a discussion, see Hall et al. (2010).

external R&D capital stocks is related to data availability and their construction entails some subjective judgement about which weighting matrix reflects knowledge flows most accurately. Ex-ante, it is not perfectly unambiguous which weighting matrix or combination of weighting matrixes would reflect the direction and intensity of R&D related knowledge flows across firms most realistically. The subjectivity in the choice of weighting matrix and the fact that knowledge spillovers can in principle also be negative[31], can lead to highly variable estimates of spillover benefits[32].

These challenges in estimating R&D output additionality and R&D spillovers should be kept in mind when reviewing these preliminary microBeRD+ results.

4.1. Cross-country analysis based on linked microBeRD and MultiProd data

Table 23 presents the results of cross-country analysis of the private returns to R&D investment, leveraging linked microBeRD and MultiProd data at the country-industry-size class level. It reports the results from estimation of a Cobb-Douglas value added production function where the factors of production are given by employment, the stock of fixed capital, stock of own-industry R&D capital and the stock of R&D capital in upstream industries. The production function is estimated in log-log form in four different specifications that differ by the type of fixed effects that the analysis controls for: only year fixed effects (columns 1 and 3) or country-size class-year fixed effects and industry-size class-year fixed effects (columns 3 and 4). All specifications indicate a labour elasticity in the range 0.64-0.71 and a fixed capital elasticity in the range 0.16-0.24 and approximately constant returns to scale.

The own-industry R&D capital elasticity is positive and statistically significant in all specifications. When only year fixed effects are included (column 1), the elasticity is estimated to be around 0.18, which implies rather high returns to own-industry R&D of 122%. A much tighter specification which controls for country-size class-year fixed effects and industry-size class-year fixed effects, effectively identifying the effects from variation across industries within each country, size group and year, the elasticity is substantially lower at around 0.05, implying smaller, but still sizeable, within-industry economic returns of 35%. These estimates are in line, for example, with estimates reported in a review by Hall, Mairesse and Mohnen (2010), who concluded that “R&D rates of return in developed economies during the past half century have been strongly positive and may be as high as 75% or so, although they are more likely to be in the 20–30% range”.

The estimated upstream industry R&D capital elasticities are also positive and statistically significant, providing tentative evidence of spillovers across industries. With only year fixed effects, the elasticity is

[31] Negative externalities may arise as other firms incur adjustment costs (Adams, 1990). To effectively employ a new technology, firms may need to invest in training or reorganise their production process. Business stealing effects represent another form of negative externality (Bloom et al., 2013). New technologies can make competing products obsolete or less valuable leading to a decline in the price and/or demand for certain products. A negative externality may likewise come into bearing if the developed knowledge is not entirely new or unique and simply a substitute to already existing knowledge.

[32] Estimated rates of return to external R&D tend to be highly variable and depend, by construction, on the number and identity of spillover recipients accounted for in the econometric analysis.

around 0.14, indicating cross-industry returns of 95%. With the stronger set of fixed effects, the elasticity is slightly reduced to 0.08, indicating returns of 54%.

Table 23. Economic returns to business R&D investment

Approach	Indirect estimation (via R&D elasticity)			
Dependent variable	log value added			
Control variables	(1)	(2)	(3)	(4)
log employment	0.707***	0.654***	0.637***	0.652***
	(0.023)	(0.031)	(0.023)	(0.030)
log fixed capital	0.167***	0.236***	0.218***	0.233***
	(0.020)	(0.025)	(0.019)	(0.024)
log R&D capital in own industry	0.183***	0.053***	0.130***	0.045***
	(0.011)	(0.017)	(0.010)	(0.017)
log R&D capital in upstream industries			0.143***	0.081**
			(0.014)	(0.032)
Year FE	Y		Y	
Country-size class-year FE		Y		Y
Industry-size class-year FE		Y		Y
Observations	5252	5252	5252	5252
Countries	10	10	10	10
Average R&D stock / VA	0.15	0.15	0.15	0.15
Implied return to R&D in own industry	**122%**	**35%**	**87%**	**30%**
Implied return to R&D in upstream industries			**95%**	**54%**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry level. The analysis covers 9 OECD countries: Austria, Belgium, Canada, Chile, France, Italy, Japan, the Netherlands, Portugal and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Overall, the analysis indicated positive and economically important returns to R&D, both within and across industries. The tighter empirical specification in fact suggests stronger cross-industry than within industry returns to R&D, and thus underscores the importance of knowledge spillovers.

The analysis based on the cell-linked microBeRD-MultiProd data has so far looked at the returns to R&D irrespective of how the R&D is funded. To investigate the impact of public support for business R&D, additional analysis takes a reduced-form approach to specifically explore the economic effects of tax incentives and direct funding. Rather than estimating elasticities with respect to R&D stocks, the reduced-form analysis estimates elasticities with respect to the B-Index and direct funding for business R&D.

The results (Table 24) provide evidence of positive and statistically significant economic effects of both tax incentives and direct support. Estimates where only tax incentives are included suggest that a 10% reduction in the B-index is associated with a 0.8% increase in value added (column 1). When only direct support is included, the results indicate that a 10% increase in direct support is associated with a 0.15% increase in value added (column 2). The results are similar also when both types of support are included jointly (column 3). Finally, when the elasticities with respect to the B-Index are allowed to vary by firm size, the point estimates are in line with stronger economic effects of R&D tax incentives for smaller firms but the differences are imprecisely estimated and not statistically significant.

Table 24. Economic effects of public support for business R&D – reduced-form estimates

Dependent variable	log value added				
Control variables	(1)	(2)	(3)	(4)	(5)
log employment	0.539***	0.549***	0.548***	0.538***	0.547***
	(0.075)	(0.072)	(0.072)	(0.075)	(0.071)
log fixed capital	0.104***	0.097***	0.100***	0.104***	0.100***
	(0.028)	(0.027)	(0.027)	(0.028)	(0.027)
log B-Index	-0.081**		-0.069*	-0.060	-0.044
	(0.035)		(0.036)	(0.076)	(0.078)
x medium (50-249 emp.)				-0.018	-0.029
				(0.091)	(0.092)
x small (10-49 emp.)				-0.045	-0.048
				(0.092)	(0.093)
log direct funding		0.015**	0.014*		0.014*
		(0.008)	(0.008)		(0.008)
Observations	3868	3868	3868	3868	3868
Countries	9	9	9	9	9

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry level. All regressions control for country-industry-size class fixed effects and industry-size class-year fixed effects. The analysis covers 9 OECD countries: Austria, Belgium, Chile, France, Italy, Japan, the Netherlands, Portugal and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

4.2. Country-specific analysis of firm-level data

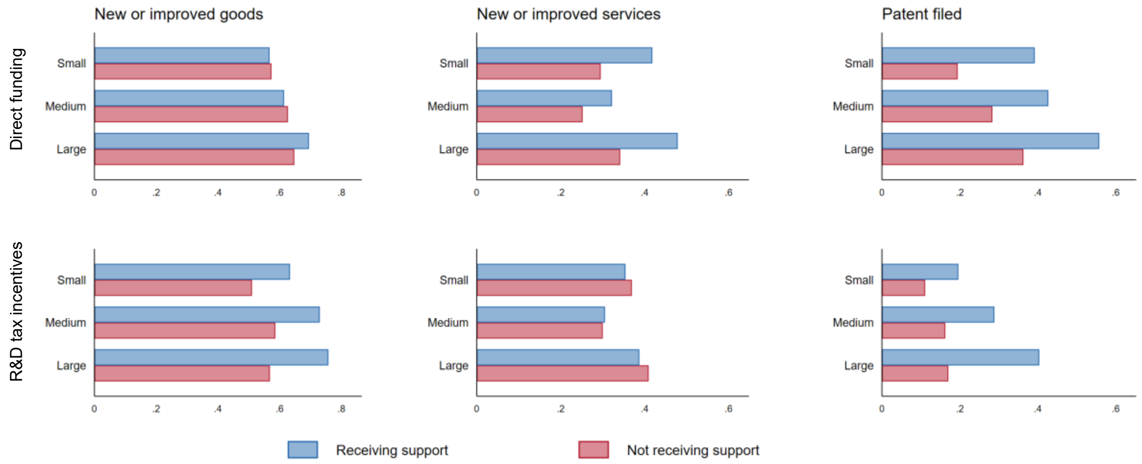
This section presents the preliminary results from the country-specific firm-level analysis of the impact of tax and direct support on innovation and economic performance. It directly builds on the firm-level R&D input additionality analysis presented in this paper and OECD (2020a), focussing on outcomes related to firms' innovation and economic performance. i.e., R&D output additionality. Following a discussion of the effects of R&D tax incentives, the results from the firm-level impact analysis on direct funding of business R&D are presented, distinguishing between direct funding from domestic government and international government institutions. The latter analysis is currently feasible for a subset of seven EU countries (Belgium, the Czech Republic, France, the Netherlands, Norway, Portugal and Sweden). Direct funding from international government institutions includes R&D funding from the European Commission which especially in EU countries may be non-negligible in size.

The new micro-aggregated statistics compiled as part of microBeRD+ for a subset of countries provide some complementary, descriptive evidence on how innovation and patenting filling rates (Figure 5 and Figure 6) and labour productivity and labour costs per employee (Figure 7) vary on average by use of tax and direct support. While there appear to be on average small differences in most innovation survey-based measures of innovation outcome between firms that use tax (direct) support and those that do not, larger scale differences seem to persist in the case of patenting and the two economic outcome measures under consideration. This descriptive evidence, while aggregated and non-causal in nature, provides a first indication of the potential difficulty of identifying the innovation impact of R&D tax incentives and direct government funding as part of the country-specific firm-level analyses based on the binary innovation measures available.

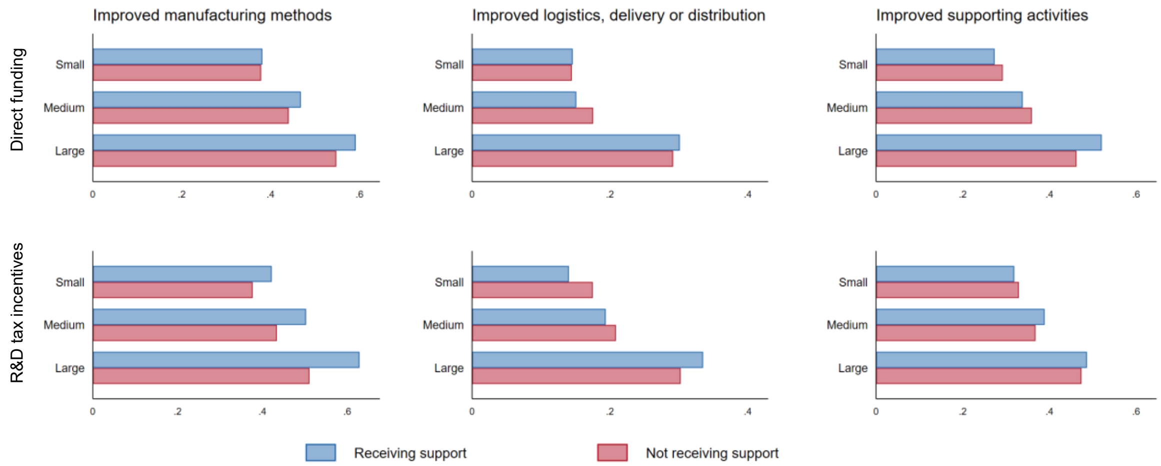
Figure 5. Innovation rates and patenting activity by use of direct and tax support

Percentage of firms introducing innovations or filing patents within each category, mean value, 2013-18

Panel A. Product innovation and patenting activity



Panel B. Process innovations

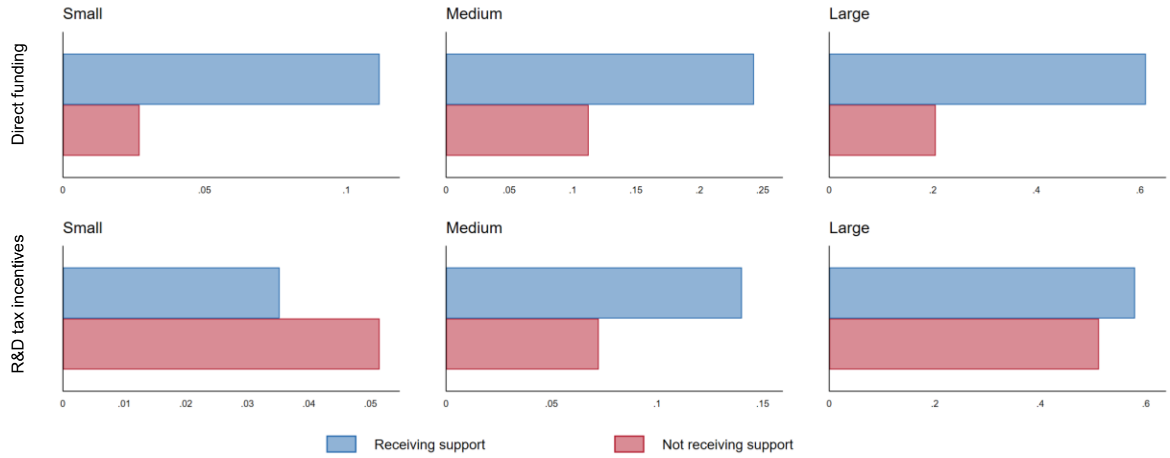


Note: The figure shows innovation rates and patenting activity across firms by size class (small, medium, large) and use of tax and direct support, based on combined business R&D (BERD) and business innovation survey microdata, linked to R&D tax relief microdata where available (see Table A.1). For each size class and type of government support, it displays averages across countries. The figure is based on average values across all years available for a given country-industry in the period 2013-2018. Countries (Direct funding): CZE, ITA, JPN, NLD, PRT, SWE. Countries (R&D tax incentives): CZE, ITA, NLD, PRT, SWE.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

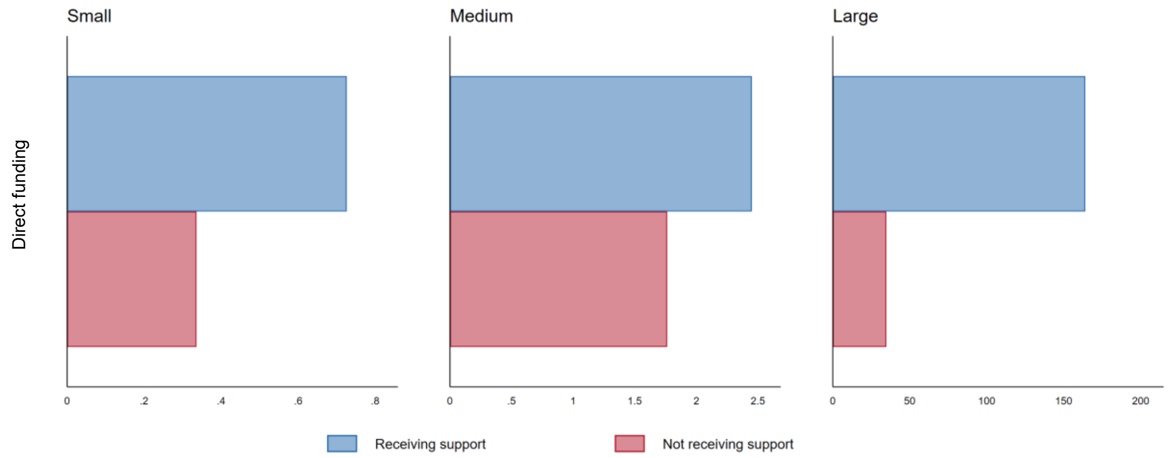
Figure 6. Patent filing activity by use of direct and tax support

Number of patent applications filed by businesses within each category, mean value, 2013-18

Panel A. Australia and the Czech Republic



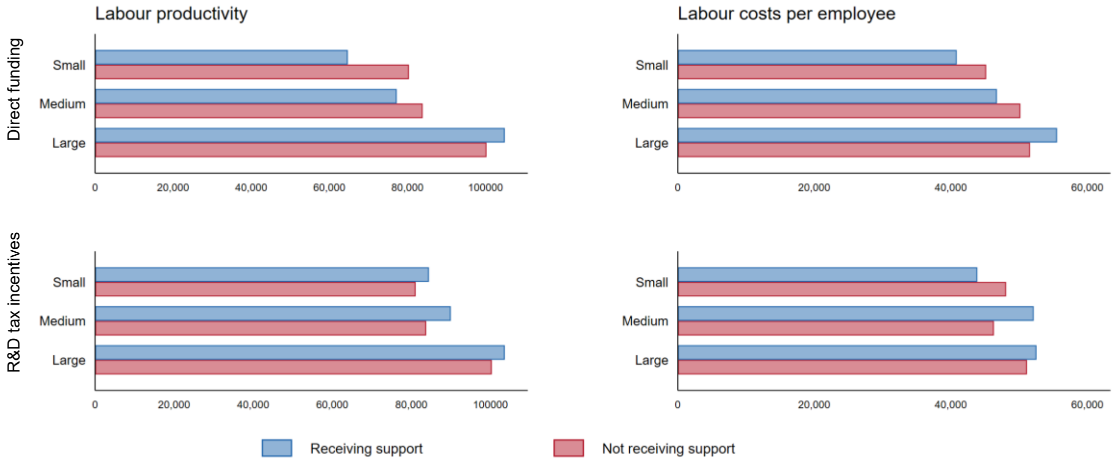
Panel B. Japan



Note: The figure shows the number of patent applications across firms by size class (small, medium, large) and use of tax and direct support, based on combined business R&D (BERD) survey and patent microdata, linked to R&D tax relief microdata where available (see Table A.1). In the case of France, the business R&D survey contains information on patent filings. For each size class (small, medium, large) and type of government support, it displays averages across countries. The figure is based on average values across all years available for a given country-industry in the period 2013-2018. Countries (Panel A - Direct funding): AUS, CZE. Countries (Panel A - R&D tax incentives): AUS, CZE. Countries (Panel B): JPN. Figures for Japan as reported separately due to the comparatively high patenting rates of firms in Japan vis-à-vis other countries in the data sample.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Figure 7. Labour productivity and labour cost per employee by use of direct and tax support

Labour productivity and labour cost per employee within each category, mean value, 2013-18



Note: The figure shows labour productivity (ratio of value added to employment) and labour cost per employee across firms by size class (small, medium, large) and use of tax and direct support, based on combined business R&D (BERD) and structural business survey microdata, linked to R&D tax relief microdata where available (see Table A.1). For each size class and type of government support, it displays averages across countries. The figure is based on average values across all years available for a given country-industry in the period 2013-2018. Countries (Direct funding): CZE, ITA, NLD, SWE. Countries (R&D tax incentives) CZE, ITA, NLD, SWE.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Innovation and economic effects

R&D tax incentives

This section presents the results from the within-country firm-level analysis of the impact of R&D tax incentives on innovation and economic outcomes.

Estimates based on business uptake of tax support

Table 25 presents the results from the impact analysis of R&D tax incentives based on policy uptake for 11 countries: Australia, Belgium, Canada, the Czech Republic, France Italy, the Netherlands, Norway, Portugal, the Slovak Republic and Sweden. To provide context for the output additionality results, column 1 shows the input additionality results for each country. The estimation yields a positive and statistically significant effect for R&D tax incentives in all countries.

Columns 2-4 display the estimated effects for three types of innovation outputs: product innovation in the form of new or substantially improved goods, product innovation in the form of new or substantially improved services and process innovation. All three outcomes take the form of binary dummy variables. Estimates for these outcomes are available for overall six countries: the Czech Republic, Italy, the Netherlands, Norway, Portugal and Sweden.

Overall, the results do not offer much evidence that would in speak in favour of R&D tax incentives leading to innovation outputs as measured in business innovation surveys. Positive and statistically significant effects are found only for goods-related product innovation in Italy and for goods-related product innovation and process innovation in Norway. All other estimates are not statistically significant, except for services related product innovation in the Czech Republic, where the effect is found to be negative and statistically significant. This outcome may be partly explained by the fact that the subsamples of firms where R&D and innovation survey data can be linked tend to be much smaller than the full R&D samples. An additional potential reason is the difficulty in aligning innovation outputs reported over a period of 3 years with changes in the uptake of support. Time lags for the implementation of innovations vis a vis R&D expenditure are an additional identification challenge, while it should also be noted that innovation outcomes may relate to activities other than R&D for which support has been identified.

Column 5 reports the estimated effects of R&D tax incentives on patenting, measured as the natural logarithm of one plus the number of patents, thus allowing to include firms with zero patent applications in a given year in the estimation sample. The results are available for six countries: Australia, Canada, the Czech Republic, France, the Netherlands and Norway. The estimated coefficients are positive for all countries with the exception of Canada, but similarly to the survey-based innovation measures, the impacts are precise enough to be statistically significant only in the case of France.

Columns 6-10 of Table 25 reports the estimated economic effects of R&D tax incentives, in particular those on sales, employment, value added, labour productivity and average wages. Sales and employment can be observed in R&D data alone and, as a result, the estimates are available for all 11 countries. In contrast, investigating effects on the other three economic outcomes requires linking the R&D data to structural business statistics microdata. Such results are available for 6 countries: Canada, France, Italy, the Netherlands, Norway and Sweden.

The results for economic outcomes paint a more positive picture than those for innovation outputs, with effects of sales, employment and value added being positive and statistically significant for a majority of countries. In particular, the effects on sales, employment are each positive and significant in all but two countries and the effects on value added in all but one country. The estimated effects on labour productivity and average labour costs per employee tend to be positive but not statistically significant.

Table 25. The impact of R&D tax incentives on innovation and economic outcomes: Diff-in-diff estimates based on business uptake of tax support

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Australia										
ATT	0.253***				0.009	0.081***	0.073***			
	(0.043)				(0.012)	(0.031)	(0.021)			
N (firms-years)	14251				14081	13890	14251			
Belgium										
ATT	0.490***					0.043	0.075***			
	(0.056)					(0.038)	(0.019)			
N (firms-years)	8636					4538	8636			
Canada										
ATT	0.229***				-0.005	0.109**	0.113***	0.130***	0.046	0.013
	(0.56)				(0.007)	(0.044)	(0.024)	(0.037)	(0.033)	(0.015)
N (firms-years)	7770				6770	6560	7700	5560	5530	5810
Czech Republic										
ATT	0.183***	-0.012	-0.101***	0.001	0.007	0.166***	0.078***			
	(0.040)	(0.018)	(0.038)	(0.031)	(0.009)	(0.030)	(0.022)			
N (firms-years)	42891	2753	2753	2753	42891	31017	42891			
France										
ATT	0.186***				0.111***	0.117***	0.091***	0.180***	0.034	0.024
	(0.025)				(0.030)	(0.034)	(0.023)	(0.059)	(0.034)	(0.015)
N (firms-years)	28793				28793	27896	28793	5574	5437	5609
Italy										
ATT	0.389***	0.053*	0.045	-0.019		0.033***	0.066***	0.036***	0.009	0.003
	(0.016)	(0.030)	(0.039)	(0.036)		(0.006)	(0.004)	(0.007)	(0.006)	(0.003)
N (firms-years)	90371	2036	2036	2036		46390	90371	33259	33201	33422

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Netherlands										
ATT	0.422***	0.043	0.046	-0.024	0.006	0.246***	0.100***	0.179**	0.026	0.083
	(0.084)	(0.067)	(0.053)	(0.068)	(0.014)	(0.070)	(0.026)	(0.072)	(0.036)	(0.056)
N (firms-years)	4179	764	764	764	4179	3454	4179	2359	2343	2423
Norway										
ATT	0.426***	0.043*	0.034	0.057**	0.012	0.105***	0.060***	0.052**	-0.016	-0.032***
	(0.033)	(0.025)	(0.023)	(0.027)	(0.007)	(0.025)	(0.015)	(0.025)	(0.017)	(0.011)
N (firms-years)	27984	5702	5702	5702	27984	26146	27984	12513	12306	12635
Portugal										
ATT	0.764***	0.006	0.025	0.048		0.176***	0.134***			
	(0.051)	(0.027)	(0.046)	(0.040)		(0.023)	(0.016)			
N (firms-years)	27516	1851	1851	1851		27130	27516			
Slovak Republic										
ATT	0.192**					0.014	0.052			
	(0.095)					(0.059)	(0.048)			
N (firms-years)	2320					2289	2320			
Sweden										
ATT	0.261***	0.011	0.057	-0.021		0.158**	0.013	-0.002	0.020	
	(0.068)	(0.035)	(0.069)	(0.066)		(0.064)	(0.052)	(0.090)	(0.038)	
N (firms-years)	2960	1375	1375	1375		2937	2960	2724	2720	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023

Table 26. The impact of R&D tax incentives on innovation and economic outcomes – Diff-in-diff estimates based on policy changes

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Australia										
ATT	0.291***				-0.000	0.178***	0.101***			
	(0.045)				(0.010)	(0.038)	(0.027)			
N (firms-years)	8326				7573	8247	8326			
Belgium										
ATT	0.243***						0.046			
	(0.073)						(0.030)			
N (firms-years)	2510						2510			
France										
ATT	0.181***				0.056*	0.083**	0.067**			
	(0.035)				(0.033)	(0.039)	(0.032)			
N (firms-years)	30085				30085	29745	30085			
Italy										
ATT	-0.061*	0.016	-0.012	-0.069*			0.026**			
	(0.032)	(0.035)	(0.040)	(0.038)			(0.010)			
N (firms-years)	19181	1825	1825	1825			19181			
Japan										
ATT	0.046**				0.078***	0.031**	-0.034***			
	(0.023)				(0.020)	(0.012)	(0.009)			
N (firms-years)	32478				32465	32451	32478			
Netherlands										
ATT	0.192***	-0.047	-0.034	0.068	0.011	0.065**	0.037***	0.001	-0.038*	-0.009
	(0.044)	(0.040)	(0.039)	(0.049)	(0.012)	(0.027)	(0.014)	(0.023)	(0.020)	(0.013)
N (firms-years)	5989	1489	1489	1489	5989	5477	5989	4528	4519	4584

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Norway (ceiling)										
ATT	0.179**				0.020	-0.121**	-0.040			
	(0.080)				(0.023)	(0.059)	(0.041)			
N (firms-years)	2028				2028	2014	2028			
Norway (user)										
ATT	0.169***				0.004	0.004	0.007			
	(0.052)				(0.018)	(0.041)	(0.026)			
N (firms-years)	4559				4559	4513	4559			
Sweden (ceiling)										
ATT	-0.037	-0.024	-0.006	0.054		0.094	0.061	0.087	0.005	
	(0.071)	(0.038)	(0.070)	(0.060)		(0.061)	(0.044)	(0.062)	(0.041)	
N (firms-years)	1673	789	789	789		1657	1673	1532	1530	
Sweden (user)										
ATT	0.117*	-0.009	0.051	0.034		0.162***	0.069**	0.100**	0.050	
	(0.065)	(0.032)	(0.050)	(0.050)		(0.049)	(0.027)	(0.048)	(0.033)	
N (firms-years)	2608	1206	1206	1206		2590	2608	2406	2402	
United Kingdom										
ATT	0.109					-0.071	-0.012		-0.081	
	(0.072)					(0.059)	(0.037)		(0.059)	
N (firms-years)	2868					2862	2868		2297	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Estimates based on policy changes

The corresponding estimates based on policy changes are displayed in Table 27. . They are available for 9 countries: Australia, Belgium, France, Italy, Japan, the Netherlands, Norway, Sweden and the United Kingdom. In the case of Norway and Sweden, two sets of estimates are reported. For each country, the first set of estimates exploits ceilings in eligible R&D expenditure and the second set of estimates that started to use the incentive once it was introduced to those that did not. The reported outcomes are the same as in the case of Table 25.

Column 1 again shows the input additionality results for each country. The estimation again yields positive and statistically significant effects for R&D tax incentives in most countries, except for the United Kingdom and the estimates for Sweden based on expenditure ceilings (the estimation for Italy shows the effects of an R&D tax incentive being removed, so the negative point estimate is indicative of positive effects of the incentive).

Columns 2-4 display estimated effects on innovation outputs. Because of limited links to the innovation survey data during the time periods around the examined policy changes, these estimates are only available for Italy, the Netherlands and Sweden. Similar to estimation based on policy use, there is little evidence of positive effects of the tax incentives on survey-based innovation outputs.

The results for patenting are shown in column 5. They are available for 5 countries: Australia, France, Japan, the Netherlands and Norway. Positive effect of R&D tax incentives are again found for France, and additionally also for Japan (which does not have results based on tax incentive use based tax data are not available). The estimates are not statistically significant for Australia, the Netherlands and Norway.

The estimates of economic effects based on policy changes are reported in columns 6-10 of Table 26. Estimates for sales and employment are available for all countries expect Italy and Belgium, where only employment is available). 5 out of 9 available estimates for sales are positive and statistically significant, and the same is true for 4 out of 10 available estimates for employment. The impacts on value added, labour productivity and average wage are available only for the Netherlands and Sweden and the United Kingdom (for labour productivity only), and only the effect on value added in Sweden is positive and statistically significant.

Overall, estimates based on policy changes mirror those based on policy uptake, with little evidence of positive effect of R&D tax incentives on survey-based innovation, some evidence for patenting and relatively strong evidence of positive economic effects.

Direct support for business R&D

This subsection discusses the results from the firm-level estimation of the effects of direct support for business R&D on innovation outputs and economic outcomes, distinguishing between direct government funding of R&D from national government vis-à-vis international government institutions.

Direct funding of business R&D from national government

Table 27 presents the results of the impact of national direct government funding of R&D on innovation and economic outcomes Estimates are available for altogether 12 countries: Belgium, Canada, the Czech Republic, France, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, and Sweden. As a point of reference, Column 1 shows the input additionality results estimated for each country. The estimates of input additionality are positive and statistically significant for all countries except for Sweden.

Columns 2-4 display the estimated effects of national direct government funding on innovation outputs for seven countries: the Czech Republic, France, Italy, the Netherlands, Norway, Portugal and Sweden. Similar to the output additionality analysis for R&D tax incentives discussed above, the output additionality analysis of direct funding yields little evidence of positive effects of direct funding on survey-based measure of innovation outcome.

Estimates of the impact of national direct government support on patenting (column 5) are also available for 6 countries: Canada, the Czech Republic, France, Japan, the Netherlands and Norway. In contrast to the results for survey-based innovation outcomes, the effect of national direct support on patenting is estimated to be positive and statistically significant for three out of six countries, namely the Czech Republic, France and Norway.

R&D survey-based estimates of the effect of direct funding on sales and employment are available for all 12 countries (columns 6-7). The results for sales are positive and statistically significant for 5 countries and the results for employment for 8 countries. Results based on linked R&D and structural business statistics data are available for 8 countries. They reveal positive and statistically significant effects of national direct funding on value added for Canada, and on average wages for Canada and New Zealand.

Direct funding of business R&D from international government institutions

Table 28 presents the impact estimates for direct government support from international government institutions which are available for 9 European countries: Belgium, the Czech Republic, France, Italy, the Netherlands, Norway, Portugal, the Slovak Republic and Sweden. As a point of reference, Column 1 shows again the input additionality results for each country. The estimation yields positive and statistically significant input additionality effects for 6 out of 9 countries, with the exceptions being Belgium, the Netherlands and the Slovak Republic.

Columns 2-4 display the results for innovation outputs, available for all countries except Belgium. Most estimates are again insignificant, but positive effects are found in the case of Italy (product innovation), Norway (both product and process innovation) and France (process innovation only).

The effects of direct support from international government institutions on patenting (column 5) have been investigated for four countries: the Czech Republic, France, the Netherlands and Norway. Statistically significant results have only been found for Norway, although the point estimates for France and the Netherlands are also positive and have a meaningful magnitude.

The estimates for sales and employment are available for all 9 countries (columns 6-7). The results for sales are positive and statistically significant only for two countries - the Czech Republic and France-, whereas those for employment are positive and statistically significant for 5 out of 9 countries. The analysis has not revealed any positive and significant effects of direct funding from international government institutions on value added, labour productivity or wages, with the exception of value added in the Czech Republic.

Table 27. The impact of national direct government funding on innovation and economic outcomes – Diff-in-diff estimates based on policy uptake

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Belgium										
ATT	0.184***					0.063	0.086***			
	(0.068)					(0.085)	(0.022)			
N (firms-years)	4323					2852	4323			
Canada										
ATT	0.208***				-0.001	0.089***	0.074***	0.078***	0.013	0.015***
	-0.016				-0.004	-0.013	-0.009	-0.013	-0.009	-0.004
N (firms-years)	652240				583050	641400	652240	616860	615860	635630
Czech Republic										
ATT	0.411***	0.014	0.035	0.067	0.016*	0.028	0.051***	-0.056	-0.028	0.007
	(0.040)	(0.020)	(0.052)	(0.049)	(0.010)	(0.038)	(0.020)	(0.037)	(0.023)	(0.009)
N (firms-years)	64490	3080	3080	3080	64490	35716	64490	28191	28165	28279
France										
ATT	0.238***	0.037	-0.007	0.040	0.072***	0.053**	0.065***	0.031	-0.029**	-0.005
	(0.024)	(0.026)	(0.081)	(0.072)	(0.028)	(0.024)	(0.018)	(0.019)	(0.014)	(0.007)
N (firms-years)	85743	923	923	923	85743	85298	85743	39888	39599	40173
Italy										
ATT	0.161***	0.055	0.049	0.064		0.005	0.040***	0.014	-0.008	0.000
	(0.029)	(0.034)	(0.051)	(0.042)		(0.019)	(0.009)	(0.017)	(0.014)	(0.007)
N (firms-years)	365779	7824	7824	7824		189119	365779	100965	100838	101282
Japan										
ATT	0.091***				0.016	0.002	-0.008			
	(0.012)				(0.013)	(0.006)	(0.005)			
N (firms-years)	907460				872502	906525	907460			

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Netherlands										
ATT	0.265***	0.060	-0.134**	-0.024	0.053	0.024	0.027	0.079	0.014	0.054
	(0.063)	(0.062)	(0.053)	(0.080)	(0.037)	(0.052)	(0.025)	(0.059)	(0.040)	(0.040)
N (firms-years)	24484	3008	3008	3008	24484	22311	24484	14785	14752	15118
New Zealand										
ATT	0.504***					0.108**	0.120***	0.002	-0.076	0.017*
	(0.096)					(0.055)	(0.037)	(0.063)	(0.048)	(0.010)
N (firms-years)	3228					2706	3228	1731	1728	1746
Norway										
ATT	0.288***	-0.051**	0.003	0.041	0.019**	0.065***	0.041***	-0.010	-0.003	0.012
	(0.030)	(0.021)	(0.020)	(0.025)	(0.009)	(0.024)	(0.013)	(0.026)	(0.021)	(0.010)
N (firms-years)	66839	13555	13555	13555	66839	64458	66839	36354	36186	36907
Portugal										
ATT	0.331***	-0.000	0.032	-0.020		0.102***	0.090***			
	(0.038)	(0.024)	(0.040)	(0.037)		(0.019)	(0.015)			
N (firms-years)	61079	4470	4470	4470		60411	61079			
Slovak Republic										
ATT	0.252*					0.081	0.035			
	(0.131)					(0.105)	(0.072)			
N (firms-years)	1893					1869	1893			
Sweden										
ATT	0.121	0.024	0.111	-0.025		0.121	0.002	-0.032	-0.083	
	(0.114)	(0.046)	(0.075)	(0.074)		(0.095)	(0.037)	(0.070)	(0.060)	
N (firms-years)	3708	1518	1518	1518		3685	3708	3410	3403	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 28. The impact of direct funding from international government institutions on innovation and economic outcomes – Diff-in-diff estimates based on policy uptake

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Belgium										
ATT	0.038					-0.015	0.013			
	(0.080)					(0.105)	(0.023)			
N (firms-years)	6816					4715	6816			
Czech Republic										
ATT	0.469***	0.032	0.027	-0.053	0.010	0.067***	0.053**	0.079***	0.008	0.002
	(0.041)	(0.033)	(0.054)	(0.055)	(0.011)	(0.022)	(0.026)	(0.022)	(0.016)	(0.009)
N (firms-years)	66663	2743	2743	2743	66663	51396	66663	34454	34415	34647
France										
ATT	0.248***	-0.008	-0.108	0.255***	0.069	0.124***	0.093**	-0.002	-0.033	-0.019
	(0.038)	(0.015)	(0.121)	(0.080)	(0.047)	(0.048)	(0.038)	(0.027)	(0.021)	(0.013)
N (firms-years)	97806	971	971	971	97806	97096	97806	44349	43990	45073
Italy										
ATT	0.210***	0.089**	0.128**	0.014		-0.026	0.042***	0.044	0.032	0.018
	(0.044)	(0.044)	(0.059)	(0.053)		(0.039)	(0.016)	(0.032)	(0.025)	(0.015)
N (firms-years)	281023	6484	6484	6484		146524	281023	77287	77196	77530
Netherlands										
ATT	-0.040	0.068	0.094	0.066	0.038	-0.064	-0.010	-0.139***	-0.116**	-0.077
	(0.074)	(0.058)	(0.068)	(0.063)	(0.067)	(0.061)	(0.030)	(0.049)	(0.046)	(0.062)
N (firms-years)	14627	2019	2019	2019	14627	13126	14627	8589	8569	8799
Norway										
ATT	0.168***	0.068	0.072*	0.110**	0.033*	0.077	0.051*	0.084	0.031	0.013
	(0.053)	(0.044)	(0.041)	(0.049)	(0.019)	(0.061)	(0.028)	(0.058)	(0.053)	(0.027)
N (firms-years)	39058	7606	7606	7606	39058	37799	39058	15915	15820	16468

Dependent variable (log unless otherwise stated)	Intramural R&D expenditure	New or improved good (0/1)	New or improved service (0/1)	Process innovation (0/1)	Patents (log(1+x))	Sales	Employment	Value added	Labour productivity	Average labour costs per employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Portugal										
ATT	0.243***	0.001	0.051	-0.061		0.031	0.052**			
	(0.063)	(0.058)	(0.056)	(0.050)		(0.033)	(0.025)			
N (firms-years)	47936	2530	2530	2530		47434	47936			
Slovak Republic										
ATT	0.234					-0.056	-0.080			
	(0.165)					(0.116)	(0.101)			
N (firms-years)	775					761	775			
Sweden										
ATT	0.282**	0.080	0.006	0.043		0.063	-0.010	0.017	-0.047	
	(0.123)	(0.095)	(0.097)	(0.100)		(0.114)	(0.050)	(0.116)	(0.070)	
N (firms-years)	2959	1015	1015	1015		2941	2959	2760	2757	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Economic returns to R&D and spillovers

Table 29 displays the preliminary results of the pilot firm-level estimation of private and public returns to business R&D. This analysis has been conducted for five pilot countries that were able to link the R&D data to structural business statistics microdata: the Czech Republic, the Netherlands, New Zealand, Norway and Sweden.

For each country, results are displayed for three different specifications. The first two specifications aim to deliver estimates of the private returns to R&D and only include each firm's own R&D stock. The first specification controls for year and industry dummies, exploiting cross-section variation within industries. The second specification includes firm fixed effects instead of industry dummies, exploiting variation over time within each firm. The third specification also controls for firm fixed effects, but it additionally accounts for the R&D stock of firms within the same 3-digit industry and for the R&D stock of firms in upstream industries, weighted by the shares of inputs purchased from each upstream industry.

The estimated elasticities for own R&D capital stock are positive for all countries and in all specifications. The pooled specifications (columns 1, 4, …) yields positive and statistically significant elasticities for all countries. The within specifications (columns 2, 5, …) yield statistically significant elasticities for the Czech Republic, the Netherlands and Norway, while the elasticities are positive but statistically insignificant in the case of New Zealand and Sweden.

Private returns to business R&D are obtained by dividing the elasticity by the ratio median ratio of R&D capital stock to value added. The private returns implied by the estimates range considerably across countries and specifications, from 56% in the within specification for the Netherlands to 5% in the within specification for Sweden. That said, these results have to be interpreted with caution, not least because of the comparative lack of precision in the elasticity estimates, which may drive large variation also in the implied private returns to R&D. On average across countries, the cross-sectional specifications yields a private return of 17% and the within specification a private return of 19%.

As expected given the mutually offsetting business-stealing and knowledge spillover effects, the estimated elasticities for R&D within own 3-digit industries are very small and not statistically significant, with the exception of New Zealand, where the elasticity is relatively large and significant. The returns implied by these estimates are close to zero, again for all countries other than New Zealand.

Finally, the elasticities with respect to R&D in upstream industries are estimated to be greater than 0.10 for all countries except Norway, although they are statistically significant only in the case of the Czech Republic. Despite the lack of precision in the elasticity estimates, these first results can be interpreted as evidence of knowledge spillovers from R&D in upstream industries. On average across all countries, the spillovers imply a public return to R&D of 17%. This would indicate the social returns to R&D – sum of private and public returns to R&D – to be about twice as large the private returns.

The returns could be different in the case of research and of development (Arqué-Castells and Spulber (2022). Table 30 explores the private and external returns separately for basic and applied research (the "R" in R&D) and experimental development (the "D"). It focuses on the third specification from Table 29, which includes firm fixed effects and measures of external R or D capital stocks.

The estimated elasticities with respect to both own research and own development are positive for all countries and statistically significant in most cases. In the case of the Czech Republic and the Netherlands, the implied private returns are similar for research and for development, while the private returns seem to be greater for research in the case of the other three countries.

The estimates for research and for development within the same narrow industry show mixed results, with different signs and mostly insignificant results (and implausibly strong negative returns in the case of Norway). The returns to research and to development in upstream industries are statistically insignificant in all cases, although the point estimates imply positive and sizeable returns in all countries except Norway. The returns again appear similar for research and for development in the Czech Republic and the Netherlands and potentially stronger for research in the case of New Zealand and Sweden.

Finally, Table 31 contains a highly exploratory analysis comparing spillovers separately for privately-funded R&D (defined as R&D expenditure minus the R&D tax relief) and for tax-funded R&D (given by the R&D tax relief). The spillovers from the tax-funded R&D turn out to be very hard to estimate, because the stock of tax-funded tends to be very small relative to both privately-funded R&D and industry value added. As a result, the estimated elasticities tend to have standard errors that are much larger than the point estimates even though the magnitude of the point estimates would indicate very large external returns to tax-funded R&D. Overall, the analysis highlights the challenges of estimating spillovers from different types of R&D funding, at least within the standard extended production function framework.

Table 29. Private and social returns to R&D

	Czech Republic			Netherlands			New Zealand			Norway			Sweden		
Dependent variable: log value added	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
log employment	0.828***	0.855***	0.855***	0.776***	0.465***	0.468***	0.900***	0.884***	0.887***	0.800***	0.543***	0.539***	0.916***	0.836***	0.837***
	(0.021)	(0.035)	(0.035)	(0.018)	(0.063)	(0.063)	(0.026)	(0.044)	(0.044)	(0.025)	(0.068)	(0.068)	(0.020)	(0.084)	(0.084)
log physical capital stock	0.187***	0.083***	0.085***	0.169***	0.062***	0.062***	0.122***	0.057***	0.055***	0.217***	0.093***	0.097***	0.083***	0.070***	0.069***
	(0.019)	(0.022)	(0.022)	(0.011)	(0.016)	(0.017)	(0.017)	(0.020)	(0.020)	(0.019)	(0.036)	(0.036)	(0.011)	(0.024)	(0.024)
log own R&D stock	0.089***	0.054**	0.051**	0.082***	0.117**	0.124***	0.027**	0.057	0.054	0.034***	0.045**	0.044**	0.055***	0.029	0.017
	(0.007)	(0.022)	(0.022)	(0.009)	(0.048)	(0.048)	(0.012)	(0.044)	(0.042)	(0.008)	(0.020)	(0.020)	(0.011)	(0.057)	(0.058)
log external R&D stock (own 3-digit industry)			0.009			-0.002			0.087*			0.017			0.013
			(0.014)			(0.037)			(0.050)			(0.046)			(0.036)
log external R&D stock (upstream industries)			0.153*			0.191			0.118			0.029			0.107
			(0.090)			(0.165)			(0.117)			(0.118)			(0.231)
N	14971	14971	14842	7757	7757	7718	2463	2463	4230	15851	15851	15768	3710	3710	3661
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry fixed effects	yes			yes			yes			yes			yes		
Firm fixed effects		yes	yes		yes	yes		yes	yes		yes	yes		yes	yes
Median own R&D stock / VA	0.40	0.40	0.40	0.21	0.21	0.21	0.43	0.43	0.43	0.50	0.50	0.50	0.59	0.59	0.59
Implied private return to R&D	**22%**	**14%**	**13%**	**39%**	**56%**	**59%**	**6%**	**13%**	**13%**	**7%**	**9%**	**9%**	**9%**	**5%**	**3%**
Median external (own 3-digit industry) R&D stock / VA			0.40			0.35			0.59			0.54			1.08
Implied external (own 3-digit industry) return to R&D			**2%**			**-1%**			**15%**			**3%**			**1%**
Median external (upstream industries) R&D stock / VA			0.39			0.91			0.85			0.42			1.65
Implied external (upstream industries) return to R&D			**39%**			**21%**			**14%**			**7%**			**6%**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 30. Private and social returns to R&D by type of R&D

	Czech Republic		Netherlands		New Zealand		Norway		Sweden	
	R	D	R	D	R	D	R	D	R	D
Dependent variable: log value added	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
log employment	0.859***	0.818***	0.803***	0.799***	0.902***	0.917***	0.763***	0.778***	0.917***	0.920***
	(0.024)	(0.026)	(0.019)	(0.018)	(0.049)	(0.027)	(0.060)	(0.054)	(0.032)	(0.024)
log physical capital stock	0.177***	0.195***	0.172***	0.177***	0.060***	0.116***	0.263***	0.240***	0.120***	0.087***
	(0.021)	(0.023)	(0.012)	(0.011)	(0.022)	(0.018)	(0.048)	(0.041)	(0.017)	(0.014)
log own R/D stock	0.069***	0.067***	0.060***	0.057***	0.013	0.023*	0.023*	0.016	0.038**	0.062***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.021)	(0.013)	(0.014)	(0.014)	(0.017)	(0.013)
log external R/D stock (own 3-digit industry)	0.022	-0.055**	0.023**	0.014	0.004	0.020	-0.158**	-0.221***	0.032	0.017
	(0.027)	(0.024)	(0.010)	(0.010)	(0.037)	(0.038)	(0.071)	(0.068)	(0.031)	(0.039)
log external R/D stock (upstream industries)	0.085	0.141	0.213	0.161	0.043	0.016	-0.288	-0.115	1.242	0.345
	(0.105)	(0.120)	(0.361)	(0.240)	(0.070)	(0.110)	(0.281)	(0.378)	(1.231)	(0.485)
N	10610	9993	6291	6574	1938	2217	2462	2865	1587	2561
Median own R/D stock / VA	0.12	0.09	0.07	0.08	0.08	0.25	0.11	0.39	0.02	0.43
Implied private return to R/D	**60%**	**74%**	**88%**	**69%**	**17%**	**9%**	**21%**	**4%**	**221%**	**14%**
Median external (own 3-digit industry) R/D stock / VA	0.17	0.23	0.11	0.15	0.14	0.40	0.14	0.42	0.13	0.79
Implied external (own 3-digit industry) return to R/D	**13%**	**-24%**	**20%**	**10%**	**3%**	**5%**	**-109%**	**-52%**	**25%**	**2%**
Median external (upstream industries) R/D stock / VA	0.19	0.22	0.42	0.24	0.27	0.42	0.16	0.25	0.31	0.97
Implied external (upstream industries) return to R/D	**45%**	**65%**	**51%**	**66%**	**16%**	**4%**	**-186%**	**-46%**	**402%**	**36%**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table 31. Private and social returns to R&D by type of R&D funding

	Czech Republic	Netherlands	Norway	Sweden
Dependent variable: log value added	(1)	(2)	(3)	(4)
log employment	0.860***	0.457***	0.593***	0.951***
	(0.037)	(0.063)	(0.028)	(0.184)
log physical capital stock	0.086***	0.058***	0.082***	0.114*
	(0.023)	(0.016)	(0.024)	(0.059)
log own R&D stock	0.052**	0.142***	0.047**	-0.034
	(0.023)	(0.046)	(0.020)	(0.079)
log external (own 3-digit industry) privately-funded R&D stock	-0.003	-0.073	-0.000	-0.009
	(0.023)	(0.049)	(0.034)	(0.219)
log external (own 3-digit industry) tax-funded R&D stock	0.011	0.067	-0.037**	-0.049
	(0.023)	(0.044)	(0.017)	(0.123)
log external (upstream industries) privately-funded R&D stock	0.131	0.193	0.085	0.995**
	(0.103)	(0.306)	(0.088)	(0.426)
log external (upstream industries) tax-funded R&D stock	0.033	0.068	0.029	1.442
	(0.084)	(0.416)	(0.165)	(1.909)
N	14345	7553	15420	1648
Median own R stock / VA	0.40	0.21	0.50	0.59
Implied private return to R&D	**13%**	**67%**	**9%**	**-6%**
Median external (own 3-digit industry) privately-funded R&D stock / VA	0.38	0.32	0.51	0.98
Implied external (own 3-digit industry) return to privately-funded R&D	**-1%**	**-23%**	**0%**	**-1%**
Median external (own 3-digit industry) tax-funded R&D stock / VA	0.02	0.03	0.03	0.00
Implied external (own 3-digit industry) return to tax-funded R&D	**68%**	**224%**	**-142%**	**-1284%**
Median external (upstream industries) privately-funded R&D stock / VA	0.38	0.87	0.41	1.47
Implied external (upstream industries) return to privately-funded R&D	**35%**	**22%**	**21%**	**68%**
Median external (upstream industries) tax-funded R&D stock / VA	0.02	0.04	0.01	0.00
Implied external (upstream industries) return to tax-funded R&D	**204%**	**154%**	**204%**	**30937%**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

5 Conclusions

This report has presented the final results from the OECD microBeRD+ project. This project set out to explore the impact of R&D tax incentives and direct funding on innovation and economic outcomes through a pilot analysis of R&D output additionality and spillovers, while also extending previous work on R&D input additionality to provide new insights on the role of policy design.

The cross-country analysis of R&D input additionality based on pooled micro-aggregated data for 21 countries has replicated the baseline and policy mix analysis carried out in the first stage of the project, leveraging an updated and extended data infrastructure and performing some additional robustness tests. The updated analysis reconfirms the evidence from the first phase of the microBeRD project (OECD, 2020a) that showed a greater business responsiveness to R&D tax incentives for small vs larger R&D performers and pointed to the relative aptitude of R&D tax incentives in encouraging experimental development vis-à-vis research, i.e. R&D closer to market application.

Another new component of the cross-country analysis has explored how the effectiveness of R&D tax incentives in encouraging additional R&D investment is linked to the design of R&D tax incentives. Businesses' responsiveness to tax incentives is estimated to be nearly twice as large when refund provision are available to loss-making firms, and three times as large when tax incentives are redeemable against payroll taxes and thus disconnected from the profit situation of firms. Refundability provision however also represent an additional cost for governments. While there is no conclusive evidence that businesses' responsiveness to R&D tax incentives would vary across different tax instruments (tax allowance vs. credit or volume-based, incremental, vs. hybrid tax incentive), there is tentative evidence that enhanced tax relief provisions for SMEs are associated with a higher (reduced) elasticity in the case of SMEs (large firms).

Input additionality is a necessary but not sufficient condition for output additionality. The pilot R&D output additionality analysis presented in this report consists of two components: (1) a cross-country analysis of the within and cross-industry economic returns to R&D, leveraging linked micro-aggregated data at country-industry-size level from the OECD microBERD and MultiProd projects, and (2) within-country firm level regression analyses on the impact of R&D tax incentives and direct funding on innovation and economic outcomes, including estimation of the private and social returns to R&D the difference in which provides a measure of the possible magnitude of knowledge spillovers from firms in upstream industries.

The cross-country analysis generates some tentative results that speak in favour of positive and statistically significant economic returns to business R&D investments within industries and even greater cross-industry returns due to knowledge spillovers. The firm-level analysis of economic performance, available for a subset of eleven countries, provides initial evidence that R&D tax incentives and direct funding have some positive effects on economic outcomes such as sales, employment, value-added, wages or labour productivity. However, the size and statistical significance of the estimated economic effect vary notably across countries and with the economic outcome measure under consideration. These cross-country differences warrant further exploration. This also holds true for the estimates from the firm-level analysis of spillovers where estimates of the private and social return to R&D are found to vary largely across the five countries covered in the pilot analysis. On average, social returns to R&D are found to be about twice as large the private returns to R&D as a result of cross-industry spillovers from upstream industries.

The results from the firm-level analyses of business innovation and patenting activity, available for a subset of six and five countries respectively, do not yet yield robust results that point to positive effects of R&D tax incentives or direct funding on innovation outputs (e.g. introducing new products and services, filing patents). Given the challenges that complicate the estimation of output additionality and limited set of countries for which estimates are currently available, these results should be taken with caution.

The cross-country and firm-level analysis carried out as part of microBeRD+ have extended the existing evidence on the R&D input additionality of R&D tax incentives and direct government funding and delivered some preliminary findings on the R&D output additionality of and tax and direct support measures. Moreover, microBeRD+ provided some new insights into the scope for measuring potential knowledge spillovers and implied social returns to R&D as part of the distributed analysis. Future OECD work will seek to corroborate the preliminary findings from the pilot output and spillover analysis and further advance the existing evidence base in this area.

microBeRD+ has contributed to developing impact analysis capabilities within and across countries, by extending the approach to newly participating countries, overcoming data access and use challenges through dialogue, and promoting record-linking between R&D input and output data. This unique multi-country infrastructure represents a valuable resource for future policy analysis and learning.

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Annex A. Data availability

Table A.1 provides an overview of the status of country participation in the two components of the microdata based analysis undertaken in the first (Panel A) and second stage of the project, distinguishing between the extended R&D input (Panel B) and pilot output (Panel C) additionality analysis in microBeRD+ and the different types of microdata sources employed in each analysis.

At the time of completing this report, 22 countries have participated in the distributed analysis undertaken in the first (2016-19) and/or second phase (2020-23) of the microBeRD project microBeRD+: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, and the United Kingdom[33]. Two countries (Germany and Switzerland) did not provide R&D tax incentives during the time period considered in this study (2000-2019), while 15 out of the 20 countries that offered R&D tax support during this period were able to either extend the analysis to tax relief microdata or to exclusively contribute tax relief microdata (Ireland) to the analysis.

The micro-aggregated statistics compiled for altogether 21 countries[34] are included in the extended, cross-country analysis of R&D input additionality. Table A.2 shows the countries and years which are included in the R&D input additionality analysis based on micro-aggregated R&D and tax relief data. Compared to the analysis undertaken in the first phase of the microBeRD project (OECD, 2020a), the extended input additionality analysis undertaken as part of microBeRD+ covers one additional country (Ireland) and leverages updated micro-aggregated statistics in the case of 13 countries.

The cross-country pilot analysis of R&D additionality and spillovers represents one new element in the distributed analysis carried out as part of microBeRD+. It leverages matched microBeRD and MultiProd micro-aggregated data that are available for ten countries (Austria, Belgium. Canada, Chile. France, Italy, Japan, Netherlands, Portugal and Sweden).

[33] In the case of the United Kingdom, the weighted micro-aggregated statistics produced in the first phase of microBeRD feature in the cross-country analysis presented in this report, while the firm level analysis relies on updated R&D survey data contributed by the United Kingdom in the second phase of microBeRD. The updated R&D survey data are unweighted and for some subcategories of R&D expenditure, values were imputed which affects the interpretation and comparability of statistics such as the share and concentration variables. The updated data cover only Great Britain and not the United Kingdom. As UK R&D statistics are in a transition period (ONS, 2022), no comparisons should at this stage be made between the micro-aggregated statistics produced as part of microBeRD and published R&D estimates.

[34] The micro-aggregated statistics for the Slovak Republic are not included in the cross-country analysis as they were not available at the time of the study.

Table A.1. Availability of outputs by type and country

microBeRD (2016-19)				
Panel A. Analysis of R&D input additionality				
		Micro-aggregated indicators (used for cross-country analysis)	**Within-country firm-level analysis**	
Policy instrument		**Tax incentives & direct support**	**Tax incentives**	**Direct support**
Source of data	**R&D survey**	8 countries AUT, CHE, DEU, ESP, GBR, ISR, JPN, NZL	2 countries AUT, JPN	2 countries AUT, JPN
	R&D survey + tax relief data	12 countries AUS, BEL, CAN, CHL, CZE, FRA, HUN, ITA, NLD, NOR, PRT, SWE	9 countries AUS, BEL, CHL, CZE, FRA, ITA, NOR, PRT, SWE	8 countries CAN, CZE, DEU, FRA, ITA, NOR, NZL, PRT
microBeRD+				
Panel B. Extended analysis of R&D input additionality				
		Micro-aggregated indicators (used for cross-country analysis)	**Within-country firm-level analysis**	
Policy instrument		**Tax incentives & direct support**	**Tax incentives**	**Direct support**
Source of data	**R&D survey**	7 countries AUT, CHE, DEU, ESP, GBR, ISR, JPN (Data update: AUT, ISR, JPN)	1 country JPN	1 country JPN
	R&D survey + tax relief data	13 countries AUS, BEL, CAN, CHL, CZE, FRA, HUN, ITA, NLD, NOR, NZL, PRT, SWE (Data update: AUS, BEL, CZE, FRA, ITA, NLD, NOR, NZL, PRT, SWE)	13 countries AUS, BEL, CAN, CZE, FRA, GBR, ITA, NLD, NOR, NZL, PRT, SVK, SWE	11 countries BEL, CAN, CZE, FRA, ITA, NLD, NOR, NZL, PRT, SVK, SWE
	Tax relief data	1 country: IRL (new)	-	-
Panel C. Pilot analysis of R&D output additionality and spillovers				
		Micro-aggregated indicators (used for cross-country analysis)	**Within-country firm-level analysis**	
Policy instrument		**Tax incentives & direct support**	**Tax incentives**	**Direct support**
Source of data	**R&D survey**	-	14 countries AUS, BEL, CAN, CZE, FRA, GBR, ITA, JPN, NLD, NOR, NZL, PRT, SVK, SWE	12 countries BEL, CAN, CZE, FRA, ITA, JPN, NLD, NOR, NZL, PRT, SVK, SWE
	R&D survey + innovation survey data	-	6 countries CZE, FRA, NLD, NOR, PRT, SWE	7 countries CAN, CZE, FRA, NLD, NOR, PRT, SWE
	R&D survey + patent data	-	7 countries AUS, CAN, CZE, FRA, JPN, NLD, NOR	6 countries CAN, CZE, FRA, JPN, NLD, NOR
	R&D survey + SBS data	-	7 countries CAN, FRA, GBR, ITA, NLD, NOR, SWE	8 countries CAN, CZE, FRA, ITA, NLD, NOR, NZL, SWE
			Returns to R&D and spillovers 5 countries: CZE, NLD, NOR, NZL, SWE	
	microBeRD+ Multiprod	AUT, BEL, CAN, CHL, FRA, ITA, JPN, NLD, PRT, SWE	-	-

Note: SBS refers to structural business survey. In the case of France, the business R&D survey contains information on patent filings. To ensure the reliability of firm-level estimates, results are only reported when the number of treated firms and the number of control firms are each at least 50. The results from the microdata analysis of R&D input additionality carried out in the first phase of the microBeRD project (Panel A) are presented in OECD (2020).
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

In the first phase of microBeRD (OECD, 2020a), firm-level regression results on the impact of R&D tax incentives and direct funding were produced for 11 (Australia, Austria, Belgium, Chile, Czech Republic, France, Italy, Japan, Norway, Portugal and Sweden) and 10 (Austria, Canada, the Czech Republic, Germany, France, Italy, Japan, Norway, New Zealand, Portugal) countries respectively.

As part of microBeRD+, firm level regression results on the impact of R&D tax incentives and direct funding have been produced for 14 countries and 12 countries, respectively. New results on the impact of R&D tax incentives are available for 6 countries (Canada, Italy, the Netherlands, New Zealand, the Slovak Republic, United Kingdom), and updated results for the other 8 countries. In the case of direct funding, microBeRD+ has produced new results for 4 countries (Belgium, the Netherlands, the Slovak Republic, Sweden) and updated results for 8 countries.

microBeRD+ has investigated the impact of public support on either innovation, economic performance or both outcomes in all 14 countries for which input additionality estimates are available. Business R&D surveys enable an assessment of the impact of government support on employment and sales, and this has been done for all 14 countries (Australia, Belgium, Canada, the Czech Republic, France, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Sweden and the United Kingdom).

However, the broader analysis of R&D output additionality hinges on the availability of additional microdata sources, notably business innovation survey, patent and structural business survey microdata. Although such data extensions are time and resource intensive, considerable data linking efforts within countries have facilitated firm-level regression analysis of the impact of government support on business innovation for 7 countries (Canada, Czech Republic, France, the Netherlands, Norway, Portugal, Sweden), on patenting activity for 7 countries (Australia, Canada, Czech Republic, France, Japan, the Netherlands, Norway) and on economic outcomes for 9 countries (Canada, Czech Republic, France, Italy, the Netherlands, Norway, New Zealand, Sweden, the United Kingdom). The pilot analysis of spillovers, relying on business R&D and structural business survey microdata (i.e. data on value-added), has been feasible for a subset of 5 countries (the Czech Republic, the Netherlands, New Zealand, Norway and Sweden).

To ensure the reliability of estimates in the R&D input and output additonality analysis, firm-level regression results are only reported when the analysis is based on a sufficiently large number of firms, specifically when the numbers of both treated firms and control firms are at least 50.

Since only a subset of participating countries have been in the position to engage in the required data linking efforts, it has not been possible to undertake a cross-country analysis of R&D output additionality solely based on the micro-aggregated statistics produced in the distributed analysis. micro-aggregated indicators of economic performances produced as part of the OECD MultiProd project help address this gap. Like microBeRD, MultiProd is an OECD project based on distributed analysis focused on microdata from Structural Business Statistics. Unlike microBeRD, covers all firms regardless of whether they perform R&D.[35]

[35] Value added, employment, capital stock (by country-A38 industry-size class cell combinations) are the microaggregate variables available for AUT, BEL, CAN, CHL, FRA, ITA, JPN, NLD, PRT, SWE

Cross-country analysis based on micro-aggregated data

Table A.2. Data availability by country and year

Year	AUS	AUT	BEL	CAN	CHE	CHL	CZE	DEU	ESP	FRA	GBR	HUN	IRL	ISR	ITA	JPN	NLD	NOR	NZL	PRT	SWE
2000				RT			RP				R					RP					
2001			R	RT			RIP	R		R	R					RP		R		R	
2002		R		RT			RP			R	R			R		RP		RT			
2003			RT	RT			RIP	R		RT	R			R		RP		RT		R	
2004		R		RT			RP			RT	R			RS		RP		RT	R		
2005	RT		RT	RT			RIP	R		RT	R			RS		RP		RT		R	
2006	RT	R		RT			RIP			RT	R			RS		RP		RT	R		
2007	RT	R	RT	RT			RTP	R	R	RT	R			RS	RS	RP		RT		RT	
2008	RT			RT	R		RTIP		R	RT	R		RT	RS	RTIS	RP		RT	R	RTI	
2009	RT	R	RT	RT		RT	RTP	R		RT	R		RT	RS	RTS	RP		RT		RT	
2010	RT			RT		RT	RTIP			RT	R		RT	RS	RIS	RP		RT	R	RTI	
2011	RT	R	RT	RT		RT	RTSP	R		RT	R		RT	RS	RS	RP		RT		RT	RIS
2012	RT			RT	R	RT	RTISP			RT	R		RT	RS	RIS	RP		RT	R	RTI	
2013		R	RT	RT		RT	RTSP	R		RT	R		RT	RS	RS	RP	RTS	RT		RT	RIS
2014	RT					RT	RTISP			RT	R	RT	RT	RS	RIS	RIP	RTIS	RT	R	RTI	
2015		R	RT		R	RT	RTSP		R	R	R	RT	RT	RS	RTS	RP	RTS	RT		RT	RTIS
2016	RT					RT	RTISP		R		R	RT	RT	RS	RTIS	RP	RTIS		R	RTI	
2017			RT		R		RTSP				R		RT	RS	RTS	RIP	RTS			RT	RTIS
2018							RTISP						RT	RS	RTS	R	RTIS		R	RTI	
2019			RT				RTSP								RTS	RI	RTS			R	

Note: R = Business R&D survey microdata; T = Tax relief microdata, I = Business innovation survey data, P = Patent microdata, S = Structural business survey microdata.
Source: OECD microBeRD project, http://oe.cd/microberd, March 2023.

Table A.3. Variables used in the input additionality analysis based on micro-aggregated data

Outcome variables	
Intramural	Total intramural R&D expenditure by firms [in the relevant cell/group]
Labour	Total R&D labour expenditure by firms
Other current	Total other current R&D expenditure by firms
Capital	Total R&D capital expenditure by firms
Extramural	Total extramural R&D expenditure by firms
Intramural (own-funded)	Total intramural (own-funded)
Intramural (own-funded) + Extramural	Total intramural (own-funded) and extramural R&D expenditure by firms
Explanatory variables	
R&D tax incentive support	
BIndex	Mean B-Index (tax component of the user cost of R&D) across firms
BIndexSyn	Mean synthetic B-Index (based on 2 year R&D lag) across firms
BIndexTax	Mean B-Index across firms based on R&D tax support use
BIndexIV	Mean B-Index across firms (based on cumulative synthetic within-firm changes) across firms
BIndexWgt	Weighted mean B-Index across firms (weights given by each firm's mean intramural R&D expenditure)
Control variables	
Value added	Total value added at country-industry (A38) level from the OECD STAN database
Fixed effects	Country-industry-size, industry-year, size-year dummy variables
Interaction variables	
Firm size	
Small	Dummy variable for small firms (10-49 employees)
Medium	Dummy variable for medium-sized firms (50-249 employees)
Large	Dummy variable for large firms (250 or more employees)
Initial R&D performance	
Initial R&D performance	Average intramural R&D expenditure of firms in the first year of observation
Low, medium & high initial R&D performance	Dummy variable for firms with average intramural R&D in the first year of obs. of less than USD 400 000 (low), USD 400 000 – 2 000 000 (medium) and more than USD 2 million (high)

Note: Variables are defined at the country-industry-size class level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table A.4. Variables used in the output additionality analysis based on micro-aggregated data

Outcome variables	
Value added	Industry value added (STAN)
Explanatory variables	
R&D variables	
R&D capital stock	R&D capital stock (microBeRD)
Control variables	
Employment	Industry employment (STAN)
Capital stock	Physical capital stock (STAN)

Note: Analysis based on linked microBeRD and STAN data. Variables are defined at the country-industry level.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Within-country analysis based on firm level data

Table A.5. Summary statistics for diff-in-diff analysis of R&D tax incentives uptake

			Employment			Intramural + Extramural			Direct support
		N	Mean	P50	SD	Mean	P50	SD	Share receiving
AUS	Control	2312	341	30	829	1904	200	4008	0.11
	Treatment	636	401	37	1324	2450	273	6679	0.15
BEL	Control	2128	313	43	802	1618	412	2921	0.34
	Treatment	630	315	167	637	6734	1052	31575	0.39
CAN									
CZE	Control	5341	287	45	482	1135	166	2885	0.35
	Treatment	544	315	42	562	1517	108	5004	0.35
FRA	Control	6770	963	162	6813	8517	892	62961	0.28
	Treatment	1465	1036	118	6480	12617	1287	62599	0.28
ITA	Control	12950	187	22	1696	3829	298	25457	0.08
	Treatment	5032	131	38	476	4923	221	26783	0.08
NLD	Control	822	262	96	956	4184	178	39657	0.03
	Treatment	218	377	58	1330	2717	202	10334	0.03
NOR	Control	3751	173	36	398	1185	23	3154	0.17
	Treatment	1261	171	20	425	1401	40	4630	0.17
PRT	Control	4367	150	27	594	587	74	2557	0.17
	Treatment	566	131	30	269	417	59	1009	0.17
SVK	Control	270	479	82	769	3217	328	6233	0.18
	Treatment	92	568	37	1298	3054	378	6049	0.18
SWE	Control	668	314	74	737	6844	1803	22310	0.14
	Treatment	267	519	65	1787	25826	1912	178852	0.14

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table A.6. Summary statistics for diff-in-diff analysis of direct funding

			Employment			Intramural + Extramural			Tax incentives
		N	Mean	P50	SD	Mean	P50	SD	Share receiving
BEL	Control	1323	187	59	467	1553	468	4238	0.4
	Treatment	318	140	14	230	1493	15	4318	0.5
CAN	Control								
	Treatment								
CZE	Control	8524	364	50	791	1091	131	3055	0.29
	Treatment	623	354	45	674	1520	114	4746	0.27
FRA	Control	18929	437	148	1207	4338	729	18226	0.59
	Treatment	884	635	94	2072	5433	556	16924	0.67
ITA	Control	62165	221	14	1267	4055	59	18104	0.35
	Treatment	1247	238	20	840	4716	192	17643	0.3
JPN	Control	120256	786	65	2353	10796	220	86804	.
	Treatment	2531	992	77	2160	14709	455	58574	.
NLD	Control	4843	379	122	1451	4388	119	27855	0.76
	Treatment	155	299	81	476	2758	991	5739	0.77
NOR	Control	10368	141	26	306	980	135	2834	0.44
	Treatment	898	153	31	326	996	198	2250	0.52
NZL	Control								
	Treatment								
PRT	Control	9624	176	32	509	775	140	3406	0.43
	Treatment	723	188	26	607	741	54	2300	0.53
SVK	Control	242	714	306	1532	4086	152	9222	0.21
	Treatment	24	784	412	712	3296	1250	3540	0.17
SWE	Control	1106	454	.	1230	15958	1300	151821	0.1
	Treatment	82	578	192	1169	8916	1310	25050	0

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. Missing values are due to data cells blanked for confidentiality reasons and countries without matched tax relief data. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.

Table A.7. Summary statistics for diff-in-diff analysis of R&D tax incentive policy changes

				Emp			IntraExt			Direct support
			N	Mean	Median	SD	Mean	Median	SD	Share receiving
AUS	Control	Large	815	1055	327	3278	7632	1885	30147	0.06
	Treatment	SME	766	42	26	68	782	431	1488	0.1
BEL	Control	Non-recipients	237	451	50	3112	1058	220	3079	.
	Treatment	Recipients	218	503	162	857	15098	2052	73466	.
FRA	Control	Non-recipients	404	847	66	7339	7193	351	98488	0.27
	Treatment	Recipients	2853	637	111	5016	9180	902	58099	0.33
ITA	Control	Non-recipients	2681	291	53	1397	2222	356	11900	0.1
	Treatment	Recipients	597	131	41	352	1134	357	5690	0.07
JPN	Control	SME	889	179	87	577	1945	329	15768	0.08
	Treatment	Large	3004	1219	448	3118	23121	2353	129248	0.14
NLD	Control	Above threshold	555	327	.	540	1496	145	1498	0.07
	Treatment	Below threshold	584	206	91	889	209	157	326	0.03
NOR	Control	Above ceiling	177	282	.	438	1747	.	1159	0.38
	Treatment	Below ceiling	213	116	72	165	256	224	152	0.36
	Control	Non-recipients	293	229	105	381	1410	272	3602	0.22
	Treatment	Recipients	474	216	68	619	2144	362	8401	0.35
SWE	Control	Above ceiling	124	910	.	1810	17548	.	22276	0.18
	Treatment	Below ceiling	349	256	79	523	2148	1321	3579	0.13
	Control	Non-recipients	459	401	155	835	5426	716	22513	0.1
	Treatment	Recipients	269	511	66	1820	25629	1955	183919	0.18

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. Missing values are due to data cells blanked for confidentiality reasons. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, July 2023.